8-2012

Consumer Sensory Preferences and Willingness-to-pay for Nutraceutical-rich Fruit

Lydia Lawless
University of Arkansas, Fayetteville

CONSUMER SENSORY PREFERENCES AND WILLINGNESS-TO-PAY FOR NUTRACEUTICAL-RICH FRUIT

CONSUMER SENSORY PREFERENCES AND WILLINGNESS-TO-PAY FOR NUTRACEUTICAL-RICH FRUIT

A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy in Food Science

By

Lydia J.R. Lawless
University of Arkansas
Bachelor of Science in Agriculture in Food Science, 2008
University of Arkansas
Bachelor of Arts in Spanish, 2009

August 2012
University of Arkansas

ABSTRACT

Health-oriented juices are prime candidates for the nutraceutical market due to their inherent healthfulness and convenience. Fruits such as açaí berries, blueberries, blackberries, black cherries, Concord grapes, cranberries, and pomegranates are rich in potentially health-supporting polyphenolics, which makes the juices of these fruits attractive for nutraceutical optimization. The compositional, sensory, and stability properties of blueberry, blackberry, and Concord grape juice blends were explored in an extended shelf-life study. Initially, 100% blueberry juice had the highest total monomeric anthocyanins (67.40 mg/100mL), 100% blackberry juice had the highest total phenolics (249.24 mg/100mL), and 100% Concord juice had the highest polymeric color (23.21%). Consumer-oriented optimization techniques based on a ten-blending-treatment mixture design were compared during a central location test (n=108). In the validation study (n=78), the desirability function solution (87% Concord + 13% blackberry) achieved the highest overall liking mean (7.55), although it was not statistically different than the ideal point solution (9% blackberry+20% blueberry+71% Concord) (6.95), the intuitive optimum (66% Concord+34% blueberry) (6.9), or 100% Concord (7.33). Willingness-to-pay (WTP) for the desirability function solution (87% Concord + 13% blackberry) was assessed with a non-hypothetical second-price experimental auction. Random effects regression showed WTP was higher when subjects tasted the product first and then received health information about anthocyanins, which indicates a contrast effect due to treatment order. Choice surveys identified the best blend out of all possible combinations of açaí, black cherry, blueberry, Concord grape, cranberry, and pomegranate juices based on antioxidant status and perceived sensory properties. The black cherry, Concord grape, and pomegranate juice blend had the highest marginal utility (x=0.51) and was further optimized with sensory affective testing (n=100). Consumer data was analyzed with a desirability function, and the optimum juice blend was 75%Con+12%Pom+13%BlkCh based on antioxidant status and sensory properties. WTP for nutraceutical juice based on antioxidant information and sensory properties was evaluated. Average WTP for the juice blend was $3.45, and average overall liking (OL) was 7.42. WTP and OL were similarly affected by variables not just-about-right (sweetness, black cherry flavor, and bitterness). WTP increased $0.25 per every unit increase in sweetness toward JAR, $0.20 per every unit decrease in black cherry flavor toward JAR, and $0.29 per every unit decrease in bitterness toward JAR.

This dissertation is approved for recommendation
to the Graduate Council.

Dissertation Director:

____

Dr. Jean-François Meullenet

Dissertation Committee:

____

Dr. Luke R. Howard

____

Dr. Andy Mauromoustakos

____

Dr. Rodolfo M. Nayga, Jr.

DISSERTATION DUPLICATION RELEASE

I hereby authorize the University of Arkansas Libraries to duplicate this dissertation when needed for research and/or scholarship.

Agreed ____

Lydia J.R. Lawless

Refused ____

Lydia J.R. Lawless

ACKNOWLEDGEMENTS

Thank you to Dr. Jean-François Meullenet, whose teaching style and interpersonal interaction showed me how excellent an advisor can be. The opportunities you have given me have changed the direction of my life. Thank you also to Dr. Renee Threlfall, whose advice and tireless editing guided me from day one. Dr. Luke Howard, thank you for patience when I was an undergraduate employee in your laboratory, and thank you for welcoming me back to A217 when my research required it. I could not have completed my doctorate without the experience I gained under your direction. Dr. Rudy Nayga, Jr., I am grateful that your expertise allowed my research to cross disciplines and my skillset to expand in profound ways. Dr. Andy Mauromoustakos, your statistical and software expertise have been very helpful over the years and for that I am grateful. My fellow graduate students and labmates were exceptional sounding boards and made this program less stressful and more enriching. Thank you to my parents, whose enthusiasm and encouragement propelled me throughout the years. Thank you also to the University of Arkansas Honors College and Graduate School, which have afforded me valuable opportunities to see the world, grow, and learn.

DEDICATION

Firstly, I dedicate this work to the administrators, teachers, and supporters of Joplin High School, who facilitated opportunities that allowed me to thrive at the University of Arkansas. In return, Joplin High School has my continued support, especially as the city rebuilds from the devastating May 22, 2011 tornado.

I also dedicate this dissertation to Grandma, whose passion for gardening and baking nursed my early interest in agriculture, and Gammy, who supported me at every horse show and awards ceremony.

Finally, I dedicate this work to my husband, Adam, with love.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER 8

LIST OF FIGURES

CHAPTER 7

CHAPTER 8

LIST OF PAPERS

Lawless, L.J.R., R.T. Threlfall, J.-F. Meullenet, and L.R. Howard. 2012 (Accepted contingent upon revision). Consumer-based optimization of blackberry, blueberry, and Concord juice blends. Journal of Sensory Studies.

Lawless, L.J.R., R. M. Nayga, Jr., F. Akaichi, J.-F. Meullenet, R.T. Threlfall, and L.R. Howard. 2012 (Accepted contingent upon revision). Willingness-to-pay for a nutraceutical-rich juice blend. Journal of Sensory Studies.

Lawless, L.J.R., R.T. Threlfall, L.R. Howard, and J.-F. Meullenet. 2012 in press. Sensory, compositional, and color properties of nutraceutical-rich juice blends. American Journal of Enology and Viticulture 64.

CHAPTER 1

Introduction

Converging factors such as an increase in social health consciousness, an aging population, and exploding healthcare expenses have enabled the nutraceutical market to morph into a multi-billion dollar industry (Basu *et al*. 2007, Mannion 1998). Expanding consumer interest in nutraceuticals has generated much scientific work on this market segment, yet many questions remain (Bernal *et al.* 2011,Nijveldt *et al.* 2001).

- How stable are health-oriented and sensory properties of nutraceutical-rich juices?
- What are the best approaches for designing and optimizing nutraceutical-rich juices to maximize consumer satisfaction?
- Are consumers willing to pay more for nutraceutical-rich juices? If so, why? What aspects of consumer psychology contribute to high willingness-to-pay (WTP) for nutraceutical-rich juice?

Fruits such as blackberries, blueberries, Concord grapes, açaí, cherries, cranberries, and pomegranates possess antioxidative, antimutagenic, and anti-inflammatory phytochemicals (Bravo 1998, Cho *et al.* 2004), which makes the juices of these fruits particularly attractive as nutraceuticals. Furthermore, beverages have the greatest future growth potential within the nutraceutical market in part because beverages such as juices are especially convenient for the consumer (Gracia *et al.* 2011, BCC Research 2011).

Unfortunately, nutraceutical compounds such as flavonoids (types of phytochemicals) can impart bitterness and astringency to juices, which may impact intensities of sensory characteristics and decrease consumer acceptance (Drewnowski and Gomez-Carneros 2000, Herrmann 1992, Robichaud and Noble 1990). Therefore, optimization strategies that consider consumer acceptance and potential health properties are highly important to the expanding nutraceutical market. Concepts from conventional product development and optimization strategies such as preference mapping, choice designs, and mixture designs can be applied and improved to determine optimal nutraceutical and sensory characteristics (Meullenet *et al.* 2008, Deliza *et al.* 2003, Kumar *et al.* 2010).

Hypothetical bias, a result of the artificial conditions under which consumers evaluate products, may permeate conventional consumer testing and weaken product development. For example, consumers may be asked to rate their overall liking or purchase intent for a product prototype, but they are not required to actually purchase it. Non-hypothetical experimental auctions advantageously eliminate hypothetical bias while eliciting WTP through exchange of real cash and products. Non-hypothetical WTP elicitation methods are especially important in the nutraceutical juice market because many fruits that are phytochemical-rich are also relatively expensive, and manufacturers must ensure that nutraceutical-rich juices maintain profitability (Reed *et al.* 2004, Herath *et al.* 2010, Seeram *et al.* 2008). Furthermore, nutraceutical-rich juices have non-sensory health characteristics, which may contribute to consumer utility; however, non-sensory characteristics are not typically captured in consumer-sensory evaluations. Experimental auctions have the potential to elicit the premium consumers are willing to pay for health characteristics aside from the product's sensory properties (Lusk and Hudson 2004).

Many demographic and attitudinal factors could potentially influence WTP for nutraceuticals (Barreiro-Hurle *et al.* 2008, Maynard and Franklin 2003). In particular, time preference, an indication of how much one values the future, and risk preference, the tendency for one to accept or reject risk, may be associated with WTP and food choices. Time preferences have been shown to predict diet choices and to relate to obesity (Huston and Finke 2003, Komlos *et al.* 2004); similarly, excess body weight has been shown to have a have a significant relationship with risk aversion (Anderson and Mellor 2008). Relationships among food choice, risk preference, and time preference suggest that these attitudes could contribute to WTP for nutraceuticals. Presumably, higher risk aversion and future orientation contributes to individuals being more protective of their future health and thus more likely to buy health-protective products; this presumption is tested in the following pages.

The objectives of this dissertation related to the initial queries were **1) to assess consumer acceptance and product stability of optimized blackberry, blueberry, and Concord juice blends, 2) to combine choice and mixture experimental designs to develop a nutraceutical-rich juice blend which maximizes consumer utility, and 3) to determine the influence of consumer characteristics, antioxidant information, and sensory properties on WTP for an optimized juice blend.** Each of these objectives represents a sub-study or group of sub-studies that have corresponding sub-objectives (Figure 1).

1.a) Determine sensory, compositional, and color properties of blackberry, blueberry, and Concord juice blends

1.a.i) Establish and relate initial descriptive sensory, compositional, and color properties of juice and juice blends

1.a.ii) Evaluate and identify drivers of consumer acceptance of nutraceutical-rich juice and juice blends

1.a.iii) Assess descriptive sensory and compositional changes during 200 days storage at 2°C and 21°C of juice and juice blends.

1.b) Compare mixture-based optimization strategies for nutraceutical-rich blackberry, blueberry, and Concord juice blends

1.c) Determine relative importance of sensory and nutraceutical information on WTP for an optimized juice blend

1.c.i) Assess the motivations behind and extent of consumer acceptance of hypothetical health statements

1.c.ii) Assess whether taste or hypothetical health statements has a greater impact on WTP and if the order in which taste and health information is presented affects WTP

2.a) Determine the three-component blend that maximizes consumer utility

2.a.i) Utilize a choice design to select the best juice blend for further optimization

2.a.ii) Identify preference, demographic, lifestyle, and attitudinal factors that influence choice

2.b) Define the properties of an optimum nutraceutical-rich juice blend

2.b.i) Determine the optimum proportions of black cherry, Concord grape, and pomegranate juice in a juice blend

2.b.ii) Describe how nutraceutical status, consumer characteristics, and sensory attributes influence consumer overall liking and purchase intent of nutraceutical-rich juice blends

3.a) Describe attitudinal factors associated with WTP for nutraceuticals

3.b) Identify significant predictors of WTP for nutraceutical juice such as risk and/or time preferences

3.c) Describe the penalty in dollars and overall liking for sensory attributes that are not just-about-right

These objectives will be addressed in the following pages.

REFERENCES

ANDERSON, L.R. and MELLOR, J.M. 2008. Predicting health behaviors with an experimental measure of risk preference. J. Health Econ. *27*, 1260-1274, DOI: 10.1016/j.jhealeco.2008.05.011.

BARREIRO-HURLE, J., COLOMBO, S. and CANTOS-VILLAR, E. 2008. Is there a market for functional wines? Consumer preferences and willingness to pay for resveratrol-enriched red wine. Food Quality and Preference *19*, 360-371, DOI: 10.1016/j.foodqual.2007.11.004.

BASU, S.K., THOMAS, J.E. and ACHA, S.N. 2007. Prospects for Growth in Global Nutraceutical and Functional Food Markets:A Canadian Perspectiv. Australian Journal of Basic and Applied Sciences *1*, 637-649.

BCC RESEARCH 2011. Nutraceuticals: Global Markets and Processing Technologies *2011*.

BERNAL, J., MENDIOLA, J.A., IBANEZ, E. and CIFUENTES, A. 2011. Advanced analysis of nutraceuticals RID B-4715-2011. J. Pharm. Biomed. Anal. *55*, 758-774, DOI: 10.1016/j.jpba.2010.11.033.

BRAVO, L. 1998. Polyphenols: Chemistry, dietary sources, metabolism, and nutritional significance. Nutr. Rev. *56*, 317-333.

CHO, M.J., HOWARD, L.R., PRIOR, R.L. and CLARK, J.R. 2004. Flavonoid glycosides and antioxidant capacity of varous blackberry, blueberry and red grape genotypes determined by high-performance liquid chromatography/mass spectrometry. J. Sci. Food Agric. *84*, 1771-1782, DOI: 10.1002/jsfa.1885.

DELIZA, R., MACFIE, H. and HEDDERLEY, D. 2003. Use of computer-generated images and conjoint analysis to investigate sensory expectations. J. Sens. Stud. *18*, 465-486, DOI: 10.1111/j.1745-459X.2003.tb00401.x.

DREWNOWSKI, A. and GOMEZ-CARNEROS, C. 2000. Bitter taste, phytonutrients, and the consumer: a review. Am. J. Clin. Nutr. *72*, 1424-1435.

GRACIA, A., LOPEZ, B. and VIRUE, S. 2011. Willingness to pay for natural juice: a choice experiment approach. Itea-Informacion Tecnica Economica Agraria *107*, 21-32.

HERATH, D., CRANFIELD, J. and HENSON, S. 2010. Understanding the financing of innovation and commercialization: the case of the Canadian functional food and nutraceutical sector. Appl. Econ. *42*, 2667-2682, DOI: 10.1080/00036840801964658.

HERRMANN, K. 1992. Bitter Compounds in Fruits and Vegetables. Ernahrungs-Umschau *39*, 14-19.

HUSTON, S.J. and FINKE, M.S. 2003. Diet choice and the role of time preference. J. Consumer Aff. *37*, 143-160.

KOMLOS, J., SMITH, P.K. and BOGIN, B. 2004. Obesity and the rate of time preference: Is there a connection?. J. Biosoc. Sci. *36*, 209-219, DOI: 10.1017/S0021932003006205.

KUMAR, S.B., RAVI, R. and SARASWATHI, G. 2010. Optimization of Fruit Punch Using Mixture Design. J. Food Sci. *75*, S1-S7, DOI: 10.1111/j.1750-3841.2009.01379.x.

LUSK, J. and HUDSON, D. 2004. Willingness-to-pay estimates and their relevance to agribusiness decision making. Rev. Agric. Econ. *26*, 152-169, DOI: 10.1111/j.1467-9353.2004.00168.x.

MANNION, M. 1998. Nutraceutical Revolution Continues at Foundation for Innovation in Medicine Conference. American Journal of Natural Medicine *5*.

MAYNARD, L.J. and FRANKLIN, S.T. 2003. Functional foods as a value-added strategy: The commercial potential of "cancer-fighting" dairy products. Review of Agricultural Economics *25*, 316-331.

MEULLENET, J.-., LOVELY, C., THRELFALL, R., MORRIS, J.R. and STRIEGLER, R.K. 2008. An ideal point density plot method for determining an optimal sensory profile for Muscadine grape juice. Food Quality and Preference *19*, 210-219, DOI: 10.1016/j.foodqual.2007.06.011.

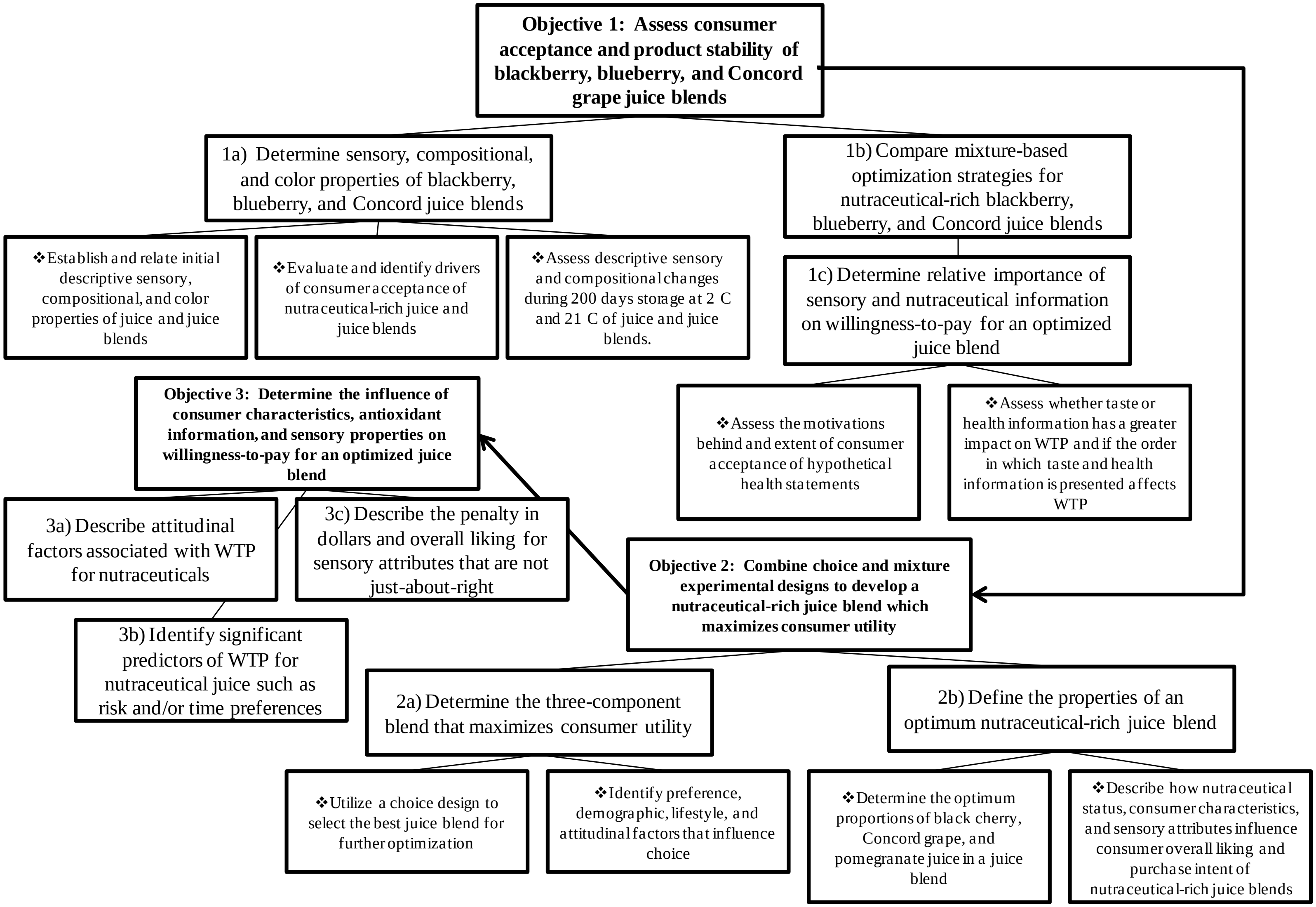
NIJVELDT, R., VAN NOOD, E., VAN HOORN, D., BOELENS, P., VAN NORREN, K. and VAN LEEUWEN, P. 2001. Flavonoids: a review of probable mechanisms of action and potential applications. Am. J. Clin. Nutr. *74*, 418-425.

, E. 2004. How much do Americans pay for fruits and vegetab , Rachel Itskowitz. In *Agriculture information bulletin ; 792-4*, [Washington, D.C.] : U.S. Dept. of Agriculture, Economic Research Service, [2004].

ROBICHAUD, J.L. and NOBLE, A.C. 1990. Astringency and Bitterness of Selected Phenolics in Wine. J. Sci. Food Agric. *53*, 342-354.

SEERAM, N.P., AVIRAM, M., ZHANG, Y., HENNING, S.M., FENG, L., DREHER, M. and HEBER, D. 2008. Comparison of antioxidant potency of commonly consumed Polyphenol-Rich beverages in the united states. J. Agric. Food Chem. *56*, 1415-1422, DOI: 10.1021/jf073035s.

FIG. 1. OUTLINE OF OBJECTIVES



CHAPTER 2

Review of Literature

I. THE ROLE OF FRUITS AND VEGETABLES IN HUMAN HEALTH

A. GENERAL BENEFITS OF FRUITS AND VEGETABLES

Fruits and vegetables have been known to have a positive effect on human health. The literature has shown that increased consumption of fruits and vegetables can decrease the occurrence of various health complications including cancer, cardiovascular disease, and stroke (Kris-Etherton *et al.* 2002; Joshipura *et al.* 2001; Knekt *et al.* 2002; Le Marchand *et al.* 2000; Garcia-Closas *et al.* 1999). The antioxidant properties of fruits and vegetables are often thought to be a contributing factor to these disease-preventing characteristics. Fruits and vegetables are known to contain antioxidants such as polyphenols, vitamins, and carotenoids (Kris-Etherton *et al.* 2002; Shi *et al.* 2001). We must note that the beneficial effects of ingesting polyphenol-rich fruit juices may not merely be due to the antioxidant capacity of the juices. In fact, polyphenol-rich fruits have been found to be influencers of enzymes such as caspase-3 and caspase-9, which can be activated to induce apoptosis of cancer cells, and role-players in cell signaling pathways (Katsube *et al.* 2003; Mertens-Talcott and Percival 2005; Chang *et al.* 2005; Wang *et al.* 1999b; Shukitt-Hale *et al.* 2009; Shukitt-Hale *et al.* 2008).

Dark fruits like those reviewed in this dissertation have been recognized as nutritional superfoods in part because they are a rich source of phytochemicals such as tannins, stillbenoids, phenolic acids, flavonoids, and lignans. Tannins exist in these fruits in forms such as proanthocyanidins, ellagitannins, and gallotannins. Stillbenoids may exist as resveratrol, and phenolic acids may be present as hydroxybenzoic and hydroxycinnamic acid derivatives. Flavonoids include anthocyanins, flavonols, and flavanols (Seeram *et al.* 2006).

B. FRUITS OF PRIMARY INTEREST

1. Blackberries and Health

Blackberries contain great potential as an ingredient in an antioxidant-potent juice blend. Dai *et. al* (2007) characterized blackberry extract developed from hull blackberries grown in Kentucky. Total anthocyanins were found to be 6.80 ± 0.31 mg/g of dried blackberry extract (DBE) (expressed as cyanidin-3-glucoside equivalent), total phenolics were found to be 17.32 ± 0.74 mg/g of DBE (expressed as gallic acid equivalent), and polymeric color was 2.2 ± 1.0%. The same blackberry extract was found to inhibit HT-29 colon tumor cell growth according to dosage of extract used. Specifically, in the course of 72 hours, 49.2 μg of total anthocyanins/ml inhibited HT-29 growth up to 66%.

Shukitt-Hale *et al.* (2009) found that rats which were fed a blackberry-supplemented diet performed better during neurological tests than control rats. For the experimental rats, freeze-dried blackberry extracts were added to the normal diet regiment. During the seventh week of treatment, the experimenters administered the following tests to the rats: rod walking, wire suspension, plank walking, inclined screen, accelerated rotarod. The blackberry-extract-fed-experimental group performed better on the accelerating rotarod, wire suspension, and small plank walk, which indicated the experimental group possessed greater balance and coordination. The Morris water maze test showed that the blackberry-extract-fed rats had better short-term memory performance.

The antioxidant capacity of blackberries can be attributed to ascorbic acid and phenolics such as anthocyanins and ellagitannins. Hassimotto *et al.* (2008) performed an *in vivo* study in which six human volunteers ingested blackberry juice prepared with water or defatted milk. The antioxidant status of the subjects' plasma and urine was taken after ingestion. Milk was included in order to assess the possible difference of the food matrix on antioxidant activity. After consumption of both blackberry juices, the authors reported that the subjects' plasma had a significant increase of ascorbic acid. Plasma antioxidant capacity had a positive correlation with ascorbic acid and no correlation with total cyanidin or total ellagic acid. The authors suggest that further studies may be needed to show the health benefits of polyphenols.

Many scientists have questioned the bioavailability of certain phytochemicals such as anthocyanins. Felgines *et al.* (2009) examined the tissue distribution of anthocyanins in blackberry-extract-fed rats. The authors note that blackberry extract was chosen because its most predominant anthocyanin, cyanidin 3-glucoside, accounts for a very large percentage of its anthocyanin content. Heart, prostate, testes, adipose, and bladder tissue samples as well as blood and urine were collected for analysis. The amount of anthocyanins found excreted in the urine accounted for only 0.20±0.03% of the anthocyanin intake, and anthocyanins were found in all of the tissues and plasma. The highest of those tested were found in the bladder. The authors note that quercetin was recently shown to induce apoptosis in bladder cancer cells (Ma *et al.* 2006) and perhaps other compounds such as anthocyanins could be shown to have the same beneficial effect. The authors conclude that understanding the tissue distribution of anthocyanins may be an important part of understanding anthocyanins' role in human health.

For many experimenters, the effects of processing and storage on antioxidants and anthocyanins are of particular interest. Hager *et al.* (2008) showed that in processed products such as canned-in-syrup blackberries, canned-in-water blackberries, pureed, and juiced blackberries, up to 75% of monomeric anthocyanins are lost during six months of storage at 25°C while changes in oxygen radical absorbance capacity ($ORAC_{FL}$) values were not statistically significant. However, for most products, processing resulted in losses of monomeric anthocyanins and antioxidant activity.

2. Blueberries and Health

Blueberries have received much attention due to their superfood status and have been studied in both *in vitro* and *in vivo* studies.

In one *in vitro* study, blueberries were found to contain anthocyanins of the types: cyanidin-3-galactoside, delphinidin-3-galatoside, petunidin-3-galactoside, petunidin-3-glucoside, petunidin-3-arabinoside, peonidin-3-galactoside, malvidin-3-galactoside, malvidin-3-glucoside, and malvidin-3-arabinoside. In this study, the authors also found that the primary tannin in blueberries was the condensed type, proanthocyanidins (Seeram *et al.* 2006).

In an *in vitro* study that tested the ability of various berry extracts to inhibit the growth of human cancer cells, blueberries showed antiproliferative properties toward all tumor cell lines used. These tumor cell lines included colon (HT-29 and HCT116), prostate (LNCaP), breast (MCF-7), and oral (KB and CAL27). Blueberries also showed pro-apoptotic effects when tested against the HT-29 colon cancer cell line. However, the author notes that the concentrations of the berry extracts used in this study were above the levels that humans can physiologically achieve. Therefore, it is important to continue the study of the potential of blueberries with *in vivo* studies (Seeram *et al.* 2006).

Several *in vivo* studies have shown promising results concerning the effects of blueberries in the neurobiology of animals. One study in particular undertaken by Joseph *et al.* (1998) found that feeding rats diet regimens supplemented with antioxidants such as Vitamin E, spinach, and strawberry actually delayed the signs of neurological aging (i.e. functionality of neurons, decreased cognitive ability, and decreased performance of motor skills). In another study, Joseph *et al.* (1999) fed aged rats supplements containing Vitamin E, spinach, strawberry, and blueberry. The rats that were fed supplements high in phytochemicals regained some of their cognitive and motor abilities. Interestingly, the blueberry-fed group showed the most improvement in their motor functions. The authors of this study caution that factors other than high-antioxidant diets contributed to the results due to the magnitude of motor function improvement. Blueberries were also shown to be effective in aiding rats in the recovery of their object recognition ability (Goyarzu *et al.* 2004).

Rats were exposed to accelerated aging through irradiation under high energy ^{56}Fe and fed fruit extracts. Feeding the rats strawberry and blueberry extracts was found to preserve the release of dopamine, which controls sensitive neuronal systems. Under normal conditions, the functionality of these systems tends to decline with age. Interestingly, the study found that blueberries had a larger impact on the striatum, the part of the brain that controls relearning, and strawberries had a larger impact on the hippocampus, which controls spatial memory (Shukitt-Hale *et al.* 2007).

Anthocyanins were identified in the tissues of euthanized pigs that were fed blueberry supplements, which showed that anthocyanins can pass the blood-brain barrier and accumulate in tissues such as the liver, eyes, and brains. This is a particularly interesting finding because it suggests that anthocyanins act at the site where their advantageous health benefits have been reported (Kalt *et al.* 2008).

3. Concord Grapes and Health

Like blueberries, Concord grapes, or *vitis labrusca,* have received attention for their antioxidative properties. This grape is a popular choice for many fruit products including jams, jellies, and dark grape juices. An *in vitro* study found that cyanidin 3-monoglucoside and delphinidin 3-monoglucoside are the major anthocyanins in Concord grapes (Munoz-Espada *et* *al.* 2004). In this same study, the total anthocyanins in Concord grape skin were found to be 330±6mg/100g skins.

Concord grape juice has prevented oxidation of human low-density lipoprotein in *in vitro* studies (Frankel *et al.* 1998), but the authors cautioned that the role of antioxidants from Concord grapes *in vitro* is not necessarily the same as their role *in vivo.* O'Byrne *et al.* (2002) compared the effects of Concord grape juice and α-tocopherol *in vivo*. 36 participants were divided into two groups. One group consumed Concord grape juice in the amount of 10 ml CGJ kg-1 d-1 per day, and one group consumed α-tocopherol in the form of a 400 IU capsule each day. The authors were interested in this comparison because previous *in vitro* studies indicated that the grape juice flavonoids were more potent antioxidants than α-tocopherol (Rice-Evans *et al.* 1996; Morand *et al.* 1998; Rice-Evans *et al.* 1995). Interestingly, O'Byrne *et al.* (2002) found that both supplements decreased LDL oxidation rate and increased serum ORAC and LDL lag time. The treatments were not found to be significantly different. The authors attributed the differing results of the *in vivo* and previous *in vitro* studies to differing absorption and retention rates of flavanoids in *in vivo* systems.

Concord grape juice has demonstrated antioxidative abilities in both *in vitro* and *in vivo* studies, which makes it an ideal candidate for a juice blend marketed toward health-conscious consumers.

4. Açaí and Health

Açaí is increasing in popularity as a nutraceutical because the Amazonian fruit has been shown to have potentially healthful properties.

A study reviewed the biochemical properties of açaí. This study found that clarified açaí juice contained 531+/- 0.2mg/ml of total anthocyanins as cyanidin-3-glucoside, and açaí pulp contained 972+/-27 mg/kg of total anthocyanins as cyanidin-3-glucoside. This indicates that there is a large amount of anthocyanins in the insoluble solids of the fruit matrix (Mertens-Talcott *et al.* 2008).

In an additional study, HPLC (high performance liquid chromatography) analysis indicated that the predominant anthocyanins in açaí are cyanidin-3-glucoside and cyanidin-3-rutinoside. This study also reviewed the effects of processing on antioxidant content. A frozen açaí concentrate was divided into three parts. The first part remained unprocessed. The second part was centrifuged and vacuum filtered through Whatman #4 filter paper. The third part was centrifuged, vacuum filtered through Whatman #4 filter paper, and passed through a 2 cm bed of diatomaceous earth. Each part was divided in half again. One half was fortified with ascorbic acid and the other was used as a control. Samples were stored at 4° C and 20°C.

The authors found that clarifying açaí pulp with diatomaceous earth resulted in a reduction of non-anthocyanin polyphenolics, antioxidant capacity, and anthocyanins; however, this process resulted in a juice that was free of lipids and insoluble solids and was a brighter red to purple color. 4°C was shown to be a better storage temperature for anthocyanin retention in açaí pulp and juice, and ascorbic acid was shown to have a detrimental effect on the anthocyanin content of açaí clarified juice (Pacheco-Palencia *et al.* 2007).

Another study examined the *in vivo* effects of açaí juice and pulp in 12 healthy volunteers. The volunteers' blood plasma was tested for antioxidant activity up to twelve hours after consuming 7ml/kg of either açaí pulp or açaí clarified juice. The volunteers' urine was tested for antioxidant capacity up to 24 hours after consumption. Consumption of the açaí pulp showed a three-fold increase in antioxidant activity. Consumption of the açaí clarified juice showed a 2.8-fold increase in antioxidant capacity. This study shows that anthocyanins from açaí juice and pulp are bioavailable in humans (Mertens-Talcott *et al.* 2008).

A proprietary beverage, MonaVie, which is currently on the market (Anonymous 2010), was studied. MonaVie contains açaí with white grape, pear, acerola, aronia, purple grape, cranberry, passion fruit, apricot, prune, kiwifruit, blueberry, wolfberry, pomegranate, lychee, camu camu, pear, banana, and bilberry juices. This study involved both *in vitro* and *in vivo* aspects and studied the effects of the juice blend in normally consumed amounts. MonaVie consumption showed an increase in blood serum antioxidant capacity within two hours for eleven out of the twelve volunteers of a randomized, double-blinded, and placebo controlled study. MonaVie consumption decreased serum lipid peroxidation within two hours for ten out of twelve of the participants. *In vivo* studies are especially important because they show the beneficial health effects of dark berries and fruits in biological systems. Common *in vitro* assays such as ORAC are useful for comparisons across fruits, but they cannot readily mimic the absorption of polyphenols in the body (Jensen *et al.* 2008).

Authors purified açaí frozen pulp, fractioned it based on solubility and affinity characteristics, and then tested the ability of açaí to initiate cancer cell death with human promyelocytic leukemia (HL-60) cells. The caspase-3 activity assay assessed açaí for pro-apoptotic ability. The principle of this assay is that caspase-3 activation leads to the split of aspartic acid-glutamic acid-valine-aspartic acid (DEVD) substrate, which in turn releases p-nitroniline. P-nitroniline can be measured spectrometrically at 405 nm. HPLC and ORAC were used to create biochemical profiles of each fraction of açaí pulp. The authors found that for most fractions, especially anthocyanin-rich ones, açaí exhibited detrimental effects toward HL-60 cell viability in a dose-dependent manner (Del Pozo-Insfran *et al.* 2006).

5. Cherries and Health

While research on cherries is limited compared to other dark fruits such as blueberries, a moderate amount of work has been done on cherries in general. A study which reviewed the phenolic content of edible fruits from Bosnia found that wild cherry (*Prunus avium L.*) had higher total phenolics than cultivated blackberry or strawberry. Total anthocyanins of the wild cherry were also higher than cultivated strawberry or blackberry (Rimpapa *et al.* 2007). Additional research shows that sweet *(Prunus avium L.)* and sour *(Prunus cerasus L.)* cherries are generally high in anthocyanins and phenolics (Gao and Mazza 1995; Wang *et al.* 1997; Wang *et al.* 1999a; Friedrich and Lee 1998).

The chemical characteristics of 13 sweet cherry cultivars including sugars, organic acids, phenolic composition, and antioxidant activity were reviewed. Generally, cherries contained glucose as the most prevalent sugar followed by fructose, sorbitol, and sucrose. Malic acid was the most prominent organic acid in the thirteen cultivars of cherries reviewed in this study. The study also reviewed the anthocyanin content of the thirteen sweet cherry cultivars. The authors identified four anthocyanins including cyanidin-3-rutinoside, cyanidin-3-glucoside, pelargonidin-3-rutinoside, and peonidin-3-rutinoside, with cyanidin-3-rutinoside being the most predominant (Usenik *et al.* 2008).

According to a review of ten cultivars of sweet cherries, cherries were highest in the following phytochemicals (in decreasing order): chlorogenic acid, epicatechin, and rutin (Veberic and Stampar 2005). Interestingly, in another study, cherry consumption decreased plasma urate in healthy women. This plasma urate reduction interested researchers because cherries have been anecdotally connected to anti-gout effects. The researchers explained that their findings support this anti-gout and anti-inflammatory reputation of cherries (Jacob *et al.*

2003). Additionally, cherry extracts have been shown to protect neuronal cells against oxidative damage in a dose-dependent fashion. The results from two *in vivo* assays, 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (MTT) reduction and trypan blue exclusion, were used to evaluate the effectiveness of the cherry extract to protect the PC 12 cell line derived from a transplantable rat pheochromocytoma. Both assays showed a positive linear relationship when anthocyanins were plotted against % cell viability. The correlations of these assays were 0.867 and 0.684 respectively (Kim *et al.* 2005).

Due to the reported potential health benefits of cherries, this fruit is ideal for consideration in a health-oriented juice blend.

6. Cranberries and Health

Recent research has demonstrated the potential of cranberries. Cranberries contain both anthocyanins and tannins. The primary anthocyanins in cranberries include cyanidin-3-glucoside, cyanidin-3-arabinoside, delphinidin-3-arabinoside, peonidin-3-galactodside, peonidin-3-glucoside, and peonidin-3-arabinoside. The most common tannins in cranberries are proanthocyanidins (Seeram 2006).

An *in vitro* study examined the ability of cranberry extract to inhibit the growth of various human tumor cell lines. Cranberry extracts, like the previously mentioned blueberry extracts, were shown to inhibit the growth of these cell lines. The efficacy of the inhibition improved with increasing concentration. However, unlike blueberry extract, cranberry extract was not shown to exhibit pro-apoptotic against the HT-29 colon cancer cell line (Seeram *et al.* 2006).

A study which investigated cranberry's usage in the prophylaxis of urinary tract infections (UTI) found that that fraction of the sample population of 150 sexually active women who consumed cranberry saw a 50% reduction in symptomatic UTI per year and a 50% reduction in antibiotic consumption. The women were randomized into three groups: cranberry juice+placebo tablets, placebo juice+cranberry tablets, and placebo juice and placebo tablets. Both the juice and the tablets were effective in reducing the occurrence of patients experiencing one urinary tract infection per year to 20% and 18% respectively (Stothers, 2002).

The ability of cranberry products to prevent urinary tract infections is thought to due to cranberry juice's interference with the adhesion of pathogenic bacteria to host tissue (Sobota, 1984; Schmidt and Sobota, 1988).

The additional benefit of prophylaxis of urinary tract infections along with the high antioxidant capacity of cranberries makes cranberry juice an ideal candidate for a novel nutraceutical beverage.

7. Pomegranates and Health

Studies indicate that the most beneficial compounds in pomegranates are ellagic acid, anthocyanidins, anthocyanins, punicic acid, flavonoids, and estrogenic flavonols. Ellagic acid in particular has been shown to be anticarcinogenic (Falsaperla *et al.* 2005) and antioxidant (Hassoun *et al.* 2004). Although ellagic acid is potentially powerful by itself, the other components of pomegranates synergistically work with ellagic acid to enhance its effectiveness (Lansky *et al.* 2005a; Lansky *et al.* 2005b).

Pomegranate juice has the most ellagitannins of any commercially available fruit juice. In fact, ellagitannins have been found to account for more than 90% of the antioxidant activity of pomegranates (Gil *et al.* 2000).

The largest of these ellagitannins is punicalagin (the largest known polyphenol), which is unique to pomegranates. Once ellagitannins are ingested, they are hydrolyzed into ellagic acid.

Additionally, intestinal microorganisms convert ellagitannins into urolithins, which inhibit prostate cancer. This anti-cancer mechanism of pomegranates has been observed in animal studies and human tissues (Heber 2008).

A storage study of reconstituted pomegranate juice identified the anthocyanins present as six major peaks including: delphinidin 3,5-diglycoside, delphinidin 3-glucoside, cyanidin 3,5-diglucoside, cyanidin 3-glucoside, pelargonidin 3, 5-diglucoside, and pelargonidin 3-glucoside with the most predominant being delphinidin 3,5-digluoside. The anthocyanin content as well as biochemical factors including pH, titratable acidity, soluble solids, and color was observed over a 210-day period at multiple storage temperatures including 4, 20, and 37 °C. At the end of the study, the juices stored at 20 and 37 °C lost the majority of their anthocyanins. This study indicates that storage time and temperature do have an impact on the phytochemical quality of a reconstituted juice; thus, when making a novel nutraceutical beverage, logistics and purchase-place conditions must be considered in order to ensure the consumer receives the highest quality product possible (Alighourchi and Barzegar, 2009).

Pomegranate extract was tested for its ability to inhibit damage to SKU-1064 human skin fibroblast cells when the cells were exposed to UVA (Ultraviolet A i.e. long wave light) and UVB (Ultraviolet B i.e. medium wave light) rays. Standardized pomegranate extract capsules were dissolved in dimethyl sulfoxide to a concentration of 100,000 mg/L and diluted to range of 0 to 10,000 mg/L for the cell culture study. The skin cells were exposed to a radiation dose of 60 mJ of UVA and UVB light for one minute. The cells were then treated with the varying dilutions of the pomegranate extract. Both UVA and UVB showed detrimental effects toward the skin cell counts. Treatment with the pomegranate extract inhibited the light-induced cell death in a dose-dependent manner. The results also indicated that the pomegranate extract afforded greater protection against UVB rays rather than UVA rays. The assays performed in this study found that pomegranate extract reduced intracellular reactive oxygen species (ROS) production and increased antioxidant capacity of the skin fibroblasts. The authors speculate that the protective abilities of pomegranate against UVA and UVB rays are linked to pomegranate's ability to regulate transduction pathways as reported in previous studies (Bowden 2004; Syed *et al.* 2007). The protective abilities of pomegranate may be linked to the regulation of protein transcription and gene expression. This study is particularly interesting because it demonstrates how polyphenolic-rich fruits like pomegranate are useful in topical applications as well as food and drink sources (Pacheco-Palencia *et al.* 2008).

An *in vivo* study investigated the effects of pomegranate juice on fertility in male rats. A group of 28 rats was divided into four groups. One group was the control and received 1 ml of distilled water while groups 2, 3, and 4 received 25% of 1 ml pomegranate juice, 50% of 1 ml pomegranate juice, and 100% of 1 ml pomegranate juice respectively by volume. At the end of the 7-week test period, the rats were tested for body and reproductive organ weight, sperm distinguishing traits, spermatogenic cell density, antioxidant vitamin levels, testosterone amounts, degree of lipid peroxidation, and enzymatic activities. The authors found that the activities of glutathione, glutathione peroxidase, and catalase increased in rats that were administered pomegranate juice. In addition, malondialdehyde levels decreased. Most interestingly, pomegranate juice consumption lead to an increase in sperm concentration and motility and lessened abnormal sperm rate when compared to rats that were administered water in place of pomegranate juice (Tuerk *et al.* 2008).

Additionally, a clinical study involving a comparison of pomegranate juice and apple juice and their ability to improve antioxidant function in elderly subjects was performed. The study involved 26 basically healthy subjects (20 men and 6 women) who were living in China. Over a four-week period, either 250 ml of pomegranate juice or 250 ml apple juice was given to each subject each morning. The subjects consumed the juice within two hours after breakfast. Blood was collected, and plasma was isolated for use in assays intended to quantify antioxidant capacity, enzymatic activities, and levels of vitamin C, vitamin E, malondialdahyde, oxidized low-density lipoprotein, carbonyls, and reduced glutathione. The authors found that pomegranate juice improved antioxidant function, as demonstrated by decreased carbonyl content and increased plasma ferric reducing/antioxidant power (FRAP) value. However, the study showed that the activity of the enzymes, superoxide dismutase (SOD), glutathione peroxidase (GSH-Px), and catalase (CAT) was not significantly different between the pomegranate and apple consumption groups. This suggests that the observed increased antioxidant activity of the pomegranate group was not due to increased enzymatic activity. The authors concluded that pomegranate juice consumption is more effective than apple juice consumption at increasing antioxidant activity in elderly patients. The researchers made a final cautionary note that due to the small sample size and short-term nature of the study, additional work is needed to verify the results (Guo *et al.* 2008).

Indeed, *in vivo* and *in vitro* studies have shown the health benefits of pomegranates. Surely, they are worth consideration in the optimization of a novel nutraceutical beverage.

II. SENSORY AND ECONOMIC INTEREST IN NUTRACEUTICALS

A. CONSUMER INTEREST IN NUTRACEUTICALS

Previous studies have shown that while many people are not familiar with the term *functional foods*, they are willing to try foods which they perceive to have an added health benefit (Ares *et al.* 2008). *Functional foods* and *nutraceuticals* are terms that describe products with value-added health benefits beyond basic nutrition.

While off-flavors tend to decrease consumer-liking, this decrease in liking could be offset with health claims especially for subgroups such as the elderly and women (Tuorila and Cardello 2002; Siegrist *et al.* 2008). Similarly, older individuals were more interested in functional foods than younger consumers (Siegrist *et al.* 2008).

Interestingly, consumers were more willing to buy yogurt than chocolate or soup even when the same benefits were described for each product. The authors explained that health claims were perceived most favorably when presented with a product that already maintained a healthy image (e.g. yogurt). The consumers were also more willing to buy products that were associated with physiological characteristics such as disease prevention rather than psychological characteristics such as stress reduction (Siegrist *et al.* 2008).

B. APPLICATIONS OF EXPERIMENTAL AUCTIONS

Experimental auctions can be used to elicit consumer WTP for value-added characteristics and have been applied to many food safety, food quality, and nutraceutical examples. When designing an experimental auction, there are many auction mechanisms from which to choose (Table 1) (Nayga 2009).

TABLE 1. EXPERIMENTAL AUCTION MECHANISMS

Name	Procedure	Structure of Auction	Number of Winners
English	Offer increasing bids one after the other	Highest bidder pays highest price	1
2^{nd} Price	Submit sealed bids to experimenter at the same time	Highest bidder pays 2^{nd} highest bid	1
nth Price	Submit sealed bids to experimenter at the same time	n-1 highest bidders pay nth highest bid	n-1
BDM (Becker-DeGroot-Marschak)	Submit sealed bids to experimenter at the same time	Players pay randomly drawn price if their bid exceeds that price	Dependent upon specific auction
Random nth price	Submit sealed bids to experimenter at the same time	n-1 highest bidders pay random (nth) bid	n-1

An Italian study determined consumer WTP for animal welfare conditions, freedom of movement and cleanliness. Two products were tested, plain and low fat yogurt. Since taste is such a strong driver of consumer acceptability and may affect WTP, panelists in this experiment expressed their WTP under three conditions: tasting without information about animal welfare, animal welfare information without tasting, and finally tasting with information concerning freedom of movement and cleanliness.

The auction technique was the Vickrey auction, another name for the second price auction, whereby all panelists submit a bid to buy the product based on taste and/or the information presented. The highest bidder purchases the product with cash and pays the second highest bid, which allows the winner to purchase the product at a price below what he is willing to pay (Vickrey 1961).

The results of this study were analyzed with Student's paired t-tests both across different information conditions and across differing combinations of animal welfare treatments.

The authors of this study found that consumers were generally willing to pay higher prices for yogurt produced from animals with more freedom of movement and cleanliness, although sensory aspects of the product also contributed to consumer WTP (Napolitano *et al.* 2008). The willingness of consumers to pay a premium to better the health and welfare of animals supports the development of nutraceutical products that may better human health and welfare.

Varying experimental auction mechanisms are used throughout the literature. Consumer WTP for increased protection against microbial contamination of ground beef through irradiation was recently examined with a dichotomous choice experiment (Nayga *et al.* 2006). WTP values were elicited using one of two methods: single bounded or one-and-a-half bounded. The authors performed the study in a grocery store setting and randomly selected participants. The researchers offered the participants a gift of one pound of non-irradiated meat and an established amount of cash. The participants were asked if they were willing to exchange their gifts for one pound of irradiated meat. If the participants refused the first offer, a second exchange was offered in the form of one pound of irradiated meat and half the original cash value. This experiment differs from the one previously discussed due to the closed nature of the monetary amounts used. The authors determined these set amounts of cash from a preliminary open-ended WTP study. The advantage of using set monetary amounts is that it more closely mimics the grocery store setting, where consumers cannot name their own price; instead, they must choose between items with set prices (Nayga 2009).

The single bound analysis assumes that the first choice made is the optimal choice for the consumer. The one-and-a-half bound approach allows for follow-up offers to be made if the first offer is rejected. Interestingly, in this experiment, both approaches yielded approximately $0.77 for consumer WTP for one pound of irradiated meat (Nayga *et al.* 2006).

Some WTP studies have examined the emotional motivations behind WTP values. A New Zealand study profiling consumer attitudes concerning ‘new’ and ‘old’ apples stressed thought listing and a mini focus group session post experimental auction to better understand consumer motivations. This study also included sensory and quantitative laboratory testing. The researchers recorded the apples’ color and firmness according to laboratory instruments and the participants’ judgments about sensory qualities. In this experiment, both WTP and willingness to accept (WTA) values were assessed. WTA is essentially the opposite of WTP in a Vickrey auction. The researchers give the participant a superior product (in this case, ‘new’ apples) and offer to pay the participants to exchange their superior product for an inferior one.

The new apples had been stored for two months in cold storage, and the old apples had been in controlled atmosphere storage for eight months. After tasting, the average liking scores and preference for the two samples were nearly equal. This is most likely due to the ‘old’ apples’ desirable sensory characteristics, which surprised many of the participants.

The thought listing and focus group exercises offered insight into the results. Some of the participants seemed more focused on bidding strategy and did not necessarily adjust their bids to their true WTP for the apples. Some participants changed their preference from new apples to old apples after tasting because the sensory characteristics of the old apples were more acceptable than they expected, and these sensory characteristics overrode the participants’ emotional attachment to having fresh apples. Some participants retained their preference for fresh apples either because they preferred them based on sensory characteristics or because they were concerned about the nutritional degradation of ‘old’ apples (Lund *et al.* 2006). The insight gleaned from the qualitative sections of this WTP experiment may benefit an experimental auction in which we wish to elicit consumer motivations and attitudes concerning the purchase of nutraceuticals.

Many experimental auctions utilize multiple bidding rounds. For example, an experimental auction, which assessed consumer WTP for a reduction in the chance of Campylobacteriosis, a foodborne illness, had twenty rounds of bidding total. In the first ten rounds, the product being auctioned was a breaded chicken sandwich described with a "lower-than-typical" risk of foodborne illness (Brown *et al.* 2005, p.251). The product initially given to the consumers was a breaded chicken sandwich with a "typical" risk of food borne illness (Brown *et al.* 2005, p.251). In rounds 11-20, participants were given more detailed risk information regarding the two products. At the end of each bidding round, the identification number of the highest bidder and the second highest bid were posted at the front of the room. At the end of all twenty rounds, one bid was randomly selected as binding, and the winning bidder had to exchange his or her sandwich at the second highest bid. The random selection of the binding round ensures that all rounds are equally important from the participants' point of view (Brown *et al.* 2005).

Some auctions have explored the influence of positive and negative information on the effects of new technology acceptance. Hayes *et. al* (2002) found that negative information outweighed positive information when consumers were presented with an irradiated pork example. Even when the source of the negative information was identified as a consumer advocacy group, consumers showed a reduction in WTP values. This study stresses the need for consumer education when introducing new technologies or products. Appropriate channels to honestly communicate the potential benefits of a high antioxidant fruit juice are essential.

Several examples indicate that when health information is shared with the consumer, the consumer is willing to pay more for some nutraceutical attributes. A recent choice experiment indicated that consumers were willing to pay a premium for resveratrol-enhanced wines. The authors estimated the premium consumers are willing to pay for this functional attribute is 5.89 €/bottle (Barreiro-Hurle *et al.* 2008). An additional study indicates consumers are willing to pay $0.41/gallon premium for functionally enhanced milk (Maynard and Franklin 2003). These studies show promising results for the future of nutraceutical beverages.

Lee and Hatcher (2001) expressed some possible disadvantages of experimental auctions in a review comparing the method to contingent valuation and conjoint analysis. While panelists are advantageously encouraged to reveal their true preferences using real money in an experimental auction, experimental pitfalls are possible and include selecting a nonrepresentative sample, introducing bias caused by the monetary incentive, increased cost, and potentially altering consumer behavior due to the artificial lab setting.

C. CONSIDERATIONS FOR TIME HORIZONS, RISK PREFERENCES, AND WTP

WTP may be affected by underlying contributors to decision making. Among these are risk and time preferences. Intertemporal choice research has explored these psychological facets and may offer insight into how they may affect WTP. Intertemporal choice involves selecting a grander deferred reward or a smaller instant reward. Early intertemporal choice studies utilized differing monetary rewards, but later, research was expanded to include health outcomes. Studies involving intertemporal choice and health outcomes have several important implications; they have the potential to explain irrational health behaviors, guide public health policy, and uncover additional understanding about psychological decision making (Chapman 2003).

1. Biases in Time Preference

Time preferences have been studied in both health and monetary domains. In the process of studying time discounting of health outcomes, certain patterns have emerged; these patterns do not necessarily match those of money outcomes, although are similar for the delay effect, magnitude effect, sign effect, sequence effect, and spreading effect, which are discussed below. Similarities between health and money outcomes diverge in certain aspects of preferences for sequence. Psychological biases have been further discussed previously (Chapman 2003; Frederick *et al.* 2002).

a. Delay and Date Effects

Generally, discount rates are greater for smaller time delays and lesser for large time delays; this phenomenon is termed the delay effect (Chapman 2003). For an example from the health domain, we can look to the case of anesthesia during childbirth. Christensen-Szalanski (1984) showed that one month *before* and *after* childbirth, women wished to avoid the use of anesthesia during childbirth. However, when women were presented with the nearly immediate outcome of pain relief *during* childbirth, they shifted their preferences toward using the anesthesia and accepting the potential long-term side effects.

Related to the delay effect is the date effect, which refers to how time is framed. When presenting a subject with two choices, one more imminent and one later, we can either use the calendar date or the actual time duration to frame the waiting time. When the calendar dates are used, discount rates tend to be lower (Read *et al.* 2005). This phenomenon can be attributed to the *attention-focusing* hypothesis, whereby using the *date* places more focus on the value of the future income, rather than the time delay. Effects known as *choice strategy*, *preference for precision*, *differential time estimation*, and the *similarity* hypothesis may also contribute and are described in more detail elsewhere (Read *et al.* 2005; Leland 2002; Rubinstein 2003). One must also note that Read *et al.* (2005) focused on monetary choices; thus, validation with health outcomes might be necessary to confirm that the effect occurs in both domains.

b. Magnitude Effect

The magnitude effect suggests that "small outcomes are discounted more than large ones" (Frederick *et al.* 2002, p.363). To measure time discount rates for the health domain, Chapman and Elstein (1995) described a perpetual state of poor health. The subjects were told to select between Treatment A, which would return them to full health immediately for a shorter duration, or Treatment B, which would take effect at a specified point in the future and be effective for a longer duration. In general, discount rates decreased with the magnitude of the health outcome. The magnitude effect, which is also demonstrated in money outcomes, suggests the presence of increasing proportional sensitivity of health and money outcomes (Chapman 2003; Prelec and Loewenstein 1991b; Loewenstein and Prelec 1992).

c. Sign Effect

The sign effect demonstrates the likely presence of loss amplification (Loewenstein and Prelec 1992; Prelec and Loewenstein 1991a) in which ratios, even if they are equivalent, feel larger if they are associated with losses rather than gains. To show this bias in the health domain, Chapman (1996b) presented a health state similar to the one discussed under the magnitude effect; however, in this study, the health outcome was sometimes presented as a gain (the subject hypothetically moves from poor health to good health) and sometimes presented as a loss (the subject hypothetically moves from good health to poor health). Discount rates were higher for gains than for losses, which indicate the presence of the sign effect.

d. Sequence Effect

Preferences for sequence have been demonstrated when individuals are presented a series of events. Generally, when choosing between individual outcomes, subjects prefer the better event sooner. However, when given a series of events, subjects tend to prefer improving sequences, although for health outcomes this pattern is abandoned for sequences that align best with previous expectations of outcomes. For example, Chapman (1996a) asked subjects to rate the attractiveness of several possible patterns for a person's health over the course of their life. The sequences were represented by bar graphs with ascending age on the abscissa and a scale of 1 to 10 on the ordinate. In some sequences, health improved over the course of one's life. In others, health decreased, while in some, health was inconsistent. Decreasing sequences were found to be preferred, which is consistent with how one usually experiences aging throughout life. However, over the short term of one-year, increasing sequences were preferred, which indicates that subjects did not expect their health to decrease over the year.

More recently, preferences for constant or increasing sequences were generally found for the health and environmental domains, though in the money domain, participants generally preferred decreasing sequences (Guyse *et al.* 2002). These results are seemingly in conflict with Chapman's work, which could be a result of the inclusion of the option for the constant sequence in the latter study and/or the differing age groups of the subject pools (undergraduate students in the former and graduate business students in the latter) (Guyse *et al.* 2002). Other studies are in agreement with Chapman's hypothesis that preferences for sequence align with expected outcomes. For example, when asked about skin problems, young women preferred an improving sequence of facial acne over an improving sequence of facial wrinkle formation to align with their expectations of the aging process (Chapman 2000).

e. Spreading Effect

The spreading effect can sometimes interfere with preferences for sequence. Generally, subjects prefer spreading out positive events. For health outcomes, this has been demonstrated when subjects were given a series of events that were both positive (e.g., chiropractor visit that relieves pain) and negative (e.g., dentist visit that causes pain) (Chapman 1998).

Research findings have supported the interplay between time preferences and risk aversion in intertemporal choice. For example, the reverse peanut effect, a situation in which subjects take bigger risks with bigger gambles, has been found to be correlated with risk and time preferences. Hence, we can conclude that at least some psychological biases are not a reflection of time preference alone but are a result of the interplay among domain, time, and likelihood (Chapman and Weber 2006). Andersen *et al.* (2008) also showed that if discount rates are defined in terms of temporally dated utility rather than income, then risk preferences (i.e., the concavity of the utility function) play an important role in time preference elicitation.

2. Risk Aversion

Differing levels of risk aversion could also contribute to differences in WTP. Risk aversion is defined as being willing to accept a lower payoff in order to avoid a riskier, greater payoff. The definition has concrete, mathematical terms. Suppose for example an individual had a choice between receiving a certain $5,000 and putting the $5,000 at risk to play for a 50% chance of getting $10,000. The risk averse individual would choose to keep the certain $5,000. The risk seeking individual would choose to play again for $10,000, and the risk neutral individual would gain the same utility from both outcomes. The risk seeking individual in this example values $10,000 twice as much as the $5,000 or gets twice the utility from $10,000 than he does from $5,000. According to the Von Neumann-Morgenstern theory of risk aversion, money obeys the law of diminishing returns, which means the more money at stake, the less utility you will gain from a set additional amount. If the risk averse individual from above would accept a 50% chance of getting a $15,000 over a guaranteed $5,000, then for this individual $15,000 offers twice the utility as $5,000. If we wanted to create a utility curve, we would use three points: ($0, 0); ($10,000, 1); ($15,000, 2) with the x-axis representing income in dollars and the y-axis representing utility in utils. From this curve, one could predict the amount of utility gained from a set amount of money. According to Von Neumann-Morgenstern's theory, risk averse behavior is rational because it always seeks to maximize utility. Allais later discussed the possibility that people may not be as rational as Von Neumann and Morgenstern assume. Allais argued that people may have different attitudes regarding large risks and small risks and those small risks may not demand the rational thought process that larger risks demand (Baker 2007).

Anderson and Mellor (2008) used a non-hypothetical lottery experiment and incorporated measures of risk preference into several models of health-related risky behaviors including cigarette smoking, heavy drinking, being obese, seat belt non-use, and driving over the speed limit. Generally, they found that the measures of risk preference were important pieces of their statistical models. If risk preferences are important in determining the likelihood of engaging in health-oriented risky behaviors; conceivably, they may be important parts of models estimating WTP for products that may reduce health risks such as a nutraceutical-oriented juice blend.

3. Measuring Time Preferences and Risk Aversion

Frederick *et al.* (2002) identified field and lab experimental studies as the two main categories of research on time preference. In lab experimental studies, the elicitation mechanisms used include choice tasks, matching task, rating tasks, and pricing tasks.

Field studies are advantageous because they represent real world behavior; however, the likelihood of confounds is high due to the difficulty in controlling all factors that affect time preference. An example of a field study is the work by Shanmugam (2006), in which discount rates were estimated using data about the risk levels in certain jobs in India.

Besides field studies, there are other time preference proxies and experimental elicitation methods. One must remember that correlation does not imply causation; thus, experimental elicitation mechanisms are better measures of time preference than proxies. Similar to field studies, time preference proxies potentially suffer from other confounds such as risk aversion.

Among the experimental elicitation mechanisms (choice, matching, rating, and pricing), choice tasks (i.e., discrete choice experiments) are the most common (Frederick *et al.* 2002). In these tasks, individuals choose between a smaller, more immediate award and a more desirable delayed award. Sometimes, these choices are made in the monetary domain and then compared to actual health-related behavior (Chesson *et al.* 2006). Alternatively, the choices relate to hypothetical health scenarios (Hardisty and Weber 2009) in which participants much choose their most preferred option.

Matching tasks are also referred to as open-choice experiments, which usually entail a "fill in the blank" approach (Frederick *et al.* 2002, p.387). Participants are given a scenario and must find the delayed equivalent of that scenario (Frederick *et al.* 2002). Responses to hypothetical health scenarios have been compared with other behaviors such as smoking status (Khwaja *et al.* 2007).

Unfortunately, the experimental elicitation mechanism itself can contribute to differing measured time discount rates as meta-analysis has shown (Percoco and Nijkamp, 2009). A comparison of close-ended and open-ended time preference elicitation mechanisms showed that close-ended mechanisms elicit lower mean discount rates, though there is consistency between social and private discount rates and between discount rates and individual traits (van der Pol and Cairns, 2008).

In rating tasks, individuals indicate how attractive a particular situation is. When this type of method is compared to others, the way in which individuals use the scale and the elicitation method have been shown to explain some of the variance in time preference studies, though health states seem to explain the largest percentage of variance (Essink-Bot *et al.* 2007). Less commonly used are pricing tasks in which individuals are asked how much they are willing to pay for a specified event at a specified time.

All of these methods have advantages and disadvantages, some of which are perhaps more pronounced in the health domain.

There are several issues which make time preference elicitation methods for health outcomes less straightforward than those for monetary outcomes. For one, elicitation mechanisms that involve monetary trade-offs can be made non-hypothetical because researchers can choose to make one or all of the choices made in the experiment binding. In other words, money outcomes can easily be made non-hypothetical or hypothetical, while health outcomes can only be made hypothetically. For a number of ethical and practical reasons, a scientist cannot enforce the choices one makes about health in a time preference experiment. Frederick *et al.* (2002) reviewed the limited studies that have compared hypothetical and non-hypothetical outcomes. Although there is evidence that discount rates are lower for hypothetical outcomes, this evidence is not substantial enough to confirm this. In one case, the discount rates from the hypothetical treatments are lower, but the hypothetical and non-hypothetical experiments were designed differently (Kirby and Marakovic, 1995). In a second case, the discount rates were only lower when censored data was not controlled (Coller and Williams, 1999) .

Conceivably, when hypothetical health states are described to participants, some of those participants have experienced a wider array of health states and thus may be able to better imagine the state being described. This may be especially true when the hypothetical state is supposed to represent an actual condition, and the subjects in the study have had or have that condition. For example, in a study which attempted to determine WTP for a quality adjusted life year (QALY) when the temporary health state was shingles, those who had suffered from shingles in the past were willing to pay more (Lieu *et al.* 2009). Likewise, those who have experienced an adverse condition place more importance on avoiding it than others who have not experienced the condition (Baron *et al.* 2003). This shows that there may be a relationship between experience and the way individuals respond to a specific hypothetical health state with which they have had experience. Perhaps there is also a relationship between those who have had more experience with a wider array of health states and how they respond in these choice tasks. This may come through age, for example. A sixty-five year old who has had heart disease has more experience with negative health states than a healthy twenty-five year old that has never had a serious condition or experienced a long hospital stay. Granted, there are some twenty-five year olds that have had serious health issues and have more experience than some sixty-five year olds, so this is not a strict example. Controlling for this experience is a difficult task because the concept is somewhat hard to define in mathematical terms.

Time preference elicitation methods in the health domain can be borrowed from time preference elicitation methods in the monetary domain. Measuring risk and time preferences is necessary because time preference and risk aversion are often confounded (i.e. risk aversion affects the curvature of the temporally dated utility function) (Andersen *et al.* 2008). Anderson and Mellor (2008) reviewed several published methods of measuring risk preference. One method utilized hypothetical gamble questions, which facilitated the researchers in classifying participants at different levels of risk aversion. Another approach to control for risk preference is to use behavior proxies. Smoking status and seat-belt use have both been validated to serve as behaviors in this capacity (Hersch and Viscusi 1990). Survey tools asking subjects to self-report their general risk-taking attitudes have also been employed. The survey data is then used to construct a binary measure of risk tolerance (Dohmen *et al.* 2005). Andersen *et al.* (2008) presented non-hypothetical elicitation methods for both time and risk preferences. Since these methods advantageously eliminate hypothetical bias (at least in the monetary domain), they will be applied in this experiment.

The objective of the following risk aversion and time preference tasks is to assess the role of time preferences and risk aversion in WTP for nutraceuticals. In all of these methods, participants are presented with a series of choices. In the risk tasks, one choice represents lesser risk with lesser reward and the other represents greater risk with greater reward. Participants who are less risk adverse will more consistently choose the riskier gambles. For explanatory purposes, a series of monetary gambles is shown in Table 2.

TABLE 2. RISK PREFERENCES FOR MONETARY OUTCOMES

Option A		Option B	
10% chance of winning $2, 90% of winning $1.60		10% chance of winning $3.85, 90% of winning $0.10	
20% chance of winning $2, 80% of winning $1.60		20% chance of winning $3.85, 80% of winning $0.10	
30% chance of winning $2, 70% of winning $1.60		30% chance of winning $3.85, 70% of winning $0.10	
40% chance of winning $2, 60% of winning $1.60		40% chance of winning $3.85, 60% of winning $0.10	
50% chance of winning $2, 50% of winning $1.60		50% chance of winning $3.85, 50% of winning $0.10	
60% chance of winning $2, 40% of winning $1.60		60% chance of winning $3.85, 40% of winning $0.10	
70% chance of winning $2, 30% of winning $1.60		70% chance of winning $3.85, 30% of winning $0.10	
80% chance of winning $2, 20% of winning $1.60		80% chance of winning $3.85, 20% of winning $0.10	
90% chance of winning $2, 10% of winning $1.60		90% chance of winning $3.85, 10% of winning $0.10	
100% chance of winning $2, 0% of winning $1.60		100% chance of winning $3.85, 0% of winning $0.10	

We would expect risk seeking individuals to choose Option B in the first few rows and risk adverse individuals to choose Option B in the last few rows. The number of times someone chooses Option A before switching to Option B (or vice versa) is an indication of the strength of their risk aversion. Risk and time coefficients generated from this method can be added as a covariate to regression models such as those used in WTP studies. The gambles shown in Table 2 are on the lower end of order of magnitudes. Additional tables with tasks of higher order of magnitudes are usually presented. To make the tasks non-hypothetical, one row from one set of tasks can randomly be selected as binding. Since the subject does not know which task will be selected as binding, s/he has an incentive to make choices that are truly representative of their risk preferences.

The strategy that Andersen *et al.* (2008) used to elicit time preferences is similar to the strategy they used to elicit risk preferences. Subjects chose between two options (see Table 3 for a monetary example). One option was more immediate but had a smaller reward. The further down a subject changed from Option A to Option B, the higher his or her time discount rate was. Like in the risk preference exercise, this number could be a covariate in regression models. The equivalent interest rate is included to enable the calculation of the time discount rate. In general, a series of tasks, each with differing orders of magnitude, should be used. The exercise can be made non-hypothetical through the random selection of one task as binding.

TABLE 3. TIME PREFERENCES FOR MONETARY OUTCOMES

Option A		**Option B**		**Interest rate**
$300 in one month		$304 in 4 months		5%
$300 in one month		$308 in 4 months		10%
$300 in one month		$311 in 4 months		15%
$300 in one month		$315 in 4 months		20%
$300 in one month		$319 in 4 months		25%
$300 in one month		$323 in 4 months		30%
$300 in one month		$326 in 4 months		35%
$300 in one month		$330 in 4 months		40%
$300 in one month		$334 in 4 months		45%
$300 in one month		$338 in 4 months		50%

We should note that the series of choices shown in Table 3 correspond to a three month time horizon. Additional tasks should be developed to capture time preferences for longer time horizons. Choice A is delayed one month (i.e., referred to as a front-end delay) because it has been suggested that subjects may perceive differing transaction costs if one choice is immediate and the other delayed (Harrison *et al.* 2002).

If we were to adapt these risk and time preference elicitation exercises to the health domain, we are still limited by the necessity for the scenarios to be hypothetical. However, we can make every effort to make the hypothetical scenarios realistic. As in the monetary examples, we can present subjects with a series of options in the health domain. The options can be described with one of many rating strategies that can be used to describe the general health state or a specific condition. The rating systems themselves can either be absolute or relative to a specific individual.

The first scale we discuss is an absolute percentage scale. In this proposed scale, 0% describes the point at which health cannot deteriorate further (i.e., state of death). 100% describes the point at which health cannot be any better (i.e., above average physical fitness and free of disease). The series of scenarios could look like the ones shown in Table 4. The percentages chosen are based on the monetary scenarios presented in Table 2. In that example, $3.85 corresponds to the best outcome, which corresponds to 100% healthy, the best outcome in Table 2. The second best outcome in Table 2 is $2.00, which corresponds to 51.9% healthy in Table 4. This is because $2.00 is 51.9% of the maximum monetary outcome, $3.85, and 51.9% healthy is 51.9% of the maximum health outcome, 100% healthy. The same approach is used to determine the other percentages.

TABLE 4. RISK PREFERENCES FOR HEALTH OUTCOMES

Option A		Option B	
10% chance of being 51.9% healthy, 90% of being 41.6% healthy		10% chance of being 100% healthy, 90% chance of being 2.60% healthy	
20% chance of being 51.9% healthy, 80% of being 41.6% healthy		20% chance of being 100% healthy, 80% of being 2.60% healthy	
30% chance of being 51.9% healthy, 70% of being 41.6% healthy		30% chance of being 100% healthy, 70% of being 2.60% healthy	
40% chance of being 51.9% healthy, 60% of being 41.6% healthy		40% chance of being 100% healthy, 60% of being 2.60% healthy	
50% chance of being 51.9% healthy, 50% of being 41.6% healthy		50% chance of being 100% healthy, 50% of being 2.60% healthy	
60% chance of being 51.9% healthy, 40% of being 41.6% healthy		60% chance of being 100% healthy, 40% of being 2.60% healthy	
70% chance of being 51.9% healthy, 30% of being 41.6% healthy		70% chance of being 100% healthy, 30% of being 2.60% healthy	
80% chance of being 51.9% healthy, 20% of being 41.6% healthy		80% chance of being 100% healthy, 20% of being 2.60% healthy	
90% chance of being 51.9% healthy, 10% of being 41.6% healthy		90% chance of being 100% healthy, 10% of being 2.60% healthy	
100% chance of being 51.9% healthy, 0% of being 41.6% healthy		100% chance of being 100% healthy, 0% of being 2.60% healthy	

The series of choices for eliciting time preference in the health domain (Table 5) is similar to those of the monetary domain. Again, the percentages of healthy correspond to the monetary exercise. 85.7% healthy corresponds to the monetary choice of $300, which is 85.7% of the maximum outcome of $350. The subjects could be given a description of a base state of health, which would be in the bottom half of the percentage scale. The subject would hypothetically stay in this base state of health until the initiation of their choice in the time preference task.

TABLE 5. TIME PREFERENCES FOR HEALTH OUTCOMES

Option A		Option B		Corresponding Monetary Interest Rate
85.7% healthy in 1 month		87.1% healthy in 4 months		5%
85.7% healthy in 1 month		88.6% healthy in 4 months		10%
85.7% healthy in 1 month		90.0% healthy in 4 months		15%
85.7% healthy in 1 month		91.4% healthy in 4 months		20%
85.7% healthy in 1 month		92.9% healthy in 4 months		25%
85.7% healthy in 1 month		94.3% healthy in 4 months		30%
85.7% healthy in 1 month		95.7% healthy in 4 months		35%
85.7% healthy in 1 month		97.1% healthy in 4 months		40%
85.7% healthy in 1 month		98.6% healthy in 4 months		45%
85.7% healthy in 1 month		100% healthy in 4 months		50%

Conceivably, several problems could arise with these scenarios. For one, subjects are being asked to imagine health states that they may not have experienced. Certainly, no one has been 0% healthy (i.e., death), and many may not have been 100% healthy (i.e., above average physical fitness while being free of disease). If this is the case, it may be better to use a relative scale and have 0% health represent the *worst health the individual subject has experienced* and 100% represent the *best health the subject has ever experienced*. This approach perhaps puts the scale in terms to which subjects can more easily understand, although other issues with this approach could still exist.

Another possible issue with the proposed series of scenarios in Table 5 is the potentially confusing use of multiple percentages. To remove the use of one set of percentages, the health scale could be a 0-10 scale in which 0 would refer to the death state and 10 to the best health possible. This would be a rating scale instead of a percentage scale. Similar rating scales have been used to evaluate subjects' preferences for sequence in the health domain (Chapman. 1996a). In Chapman's study (1996a, p.61), 10 referred to "perfect health, the best [the subject] can imagine" and 1 to "very poor health, just barely better than death". Visual analogue scales in which 0 refers to death and 100 to full health have been used in QALY studies as well (Essink-Bot *et al.* 2007).

The third issue that could arise with the scenarios in Table 5 is the discomfort that subjects could experience pondering the death state. An alternative, less extreme scale might have a bottom that corresponds to below average health (for the individual) and the top to above average health (for the individual).

All of the approaches for measuring time preference presented thus far have focused on a general health state, which is similar to some previous literature (for example, (Chapman and Elstein 1995; Chapman 1996a). Perhaps subjects could better imagine the health state if it were more specific. The approach of many time preference studies is to frame the time preference measure in a particular state (for example, during childbirth (Christensen-Szalanski 1984), influenza (Chapman and Coups. 1999), or influenza and chest pain (Chapman *et al.* 2001)). In this case, the previously discussed approaches could be adapted to be more specific. For example, in Tables 4 and 5, the choices could revolve around the chances of not getting a specific disease such as heart disease or cancer. In Table 5, the first row could be a choice between an 85.7% chance of avoiding lung cancer in one month and 87.1% chance of avoiding lung cancer in four months. Since the onset of some conditions is somewhat associated with age, then time horizons should be adjusted appropriately.

Risk and time preferences elicited with these exercises could have implications in determining marketability of products that may help prevent particular diseases; thus, addressing the contribution of time discount rates and risk aversion to WTP for nutraceuticals is a worthy contribution to the literature.

D. AFFECTIVE CONSUMER TESTING

Quantitative consumer testing assesses the reactions of large groups of consumers to products via a questionnaire. Consumer testing is suitable for establishing overall liking or preference, ascertaining liking for broad product characteristics (e.g. aroma, flavor, appearance, texture), and determining consumer responses to specific product attributes (e.g. sweetness, tartness).

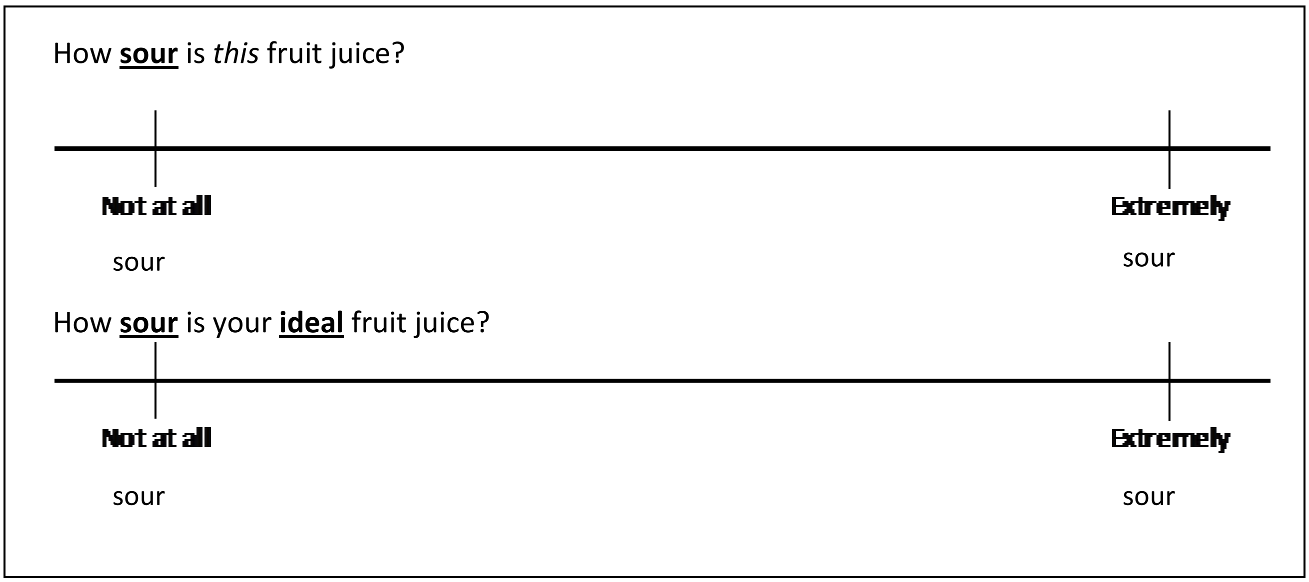
Acceptance tests are appropriate when a researcher wishes to determine a product's affective status. Multiple products can be compared with the scores obtained. The most effective scales are balanced with equally-weighted positive and negative word anchors (Meilgaard *et al.* 2007).

The nine-point hedonic scale was originally developed in the 1950s and quickly achieved wide adoption and utilization (Peryam and Pilgrim 1957). Though this scale has relative ease of use, it utilizes predetermined categories, which are possibly unequally spaced (Moskowitz 1980). Thus, the data obtained with this scale is ordinal; therefore, many argue that the data obtained with this scale must be analyzed with non-parametric statistics. Furthermore, consumers tend to avoid using end-categories, which limits the ability of the scale to differentiate between extremely liked and extremely disliked products.

The shortcomings of the nine-point verbal hedonic scale necessitate exploration of better scaling methods. A portion of this study will explore ideal point scales, which can determine the overall distance from a product to the consumer's ideal product (Oupadissakoon and Meullenet

2009). Ideal point scales for attributes can determine the distance of specific product attributes to consumers' ideal levels of attributes (e.g. sweetness, sourness, fruit flavor intensity). Possible anchors for the overall ideal point scale may be *not at all like my ideal* and *ideal*. Attribute testing for sourness, for example, may also be examined as follows (Figure 1).

FIG. 1. IDEAL ATTRIBUTE INTENSITY EXAMPLE



E. PRODUCT OPTIMIZATION

1. Choice Designs

In a typical choice design, the participant chooses his most preferred combination from a set. Conjoint analysis is a specialized choice design where products are made of a combination of attributes, and the consumer ranks or rates the products (Kuhfeld 2010). Choice designs can be used as screening methods to narrow a broad range of possible products to a feasible number of testable products. They can also be used to optimize packaging attributes as follows.

The use of computer-generated images and conjoint analysis to optimize passion fruit juice packaging was investigated. Researchers recruited 125 consumers in the UK who were not previously familiar with passion fruit juice. Using previous work as a guide, researchers selected background color, picture, information, brand, language, and shape as attributes to optimize. The consumer panel was divided based on a need for cognition (NFC) survey. The NFC survey was used in order to distinguish between consumers who enjoy analyzing information from those who are more passive. The impact of each packaging characteristic on the following expected sensory attributes (e.g., naturalness, freshness, refreshing, sharpness, pureness, sweetness) was examined. The label information and the background color were the most important attributes. The information treatments were 1) no information on the label; 2) the quantity (1 liter) and "pure" on the label; and 3) the quantity (1 liter), "100% pure", "natural", "not made from concentrate", "use by date", and "rich in Vitamin A" on the label (Deliza *et al.* 2003, p. 470). Communicating nutraceutical information to the consumer via packaging is an important aspect of developing a nutraceutical-rich beverage.

2. Mixture Designs

A mixture experiment is one in which the components of the experiment are represented by their relative proportions, and the proportions must sum to one. In mixture designs, no one factor can be isolated without changing another factor. Thus, the analysis and interpretation of mixture experiments is fundamentally different from those of factorial experiments (Cornell 1981). Many mixture designs have been developed including the simplex lattice, simplex centroid, and ABCD design. Software packages (e.g. JMP®) can create custom models, which are especially useful if there are known desired constraints on the mixture space.

Mixture designs have previously been applied to optimize beverages such as tropical fruit punch and red wine (Kumar *et al.* 2010; Dooley *et al.* 2011). However, many optimizations are solely based on sensory properties. For nutraceuticals, optimizations could consider sensory and potential health properties such as total polyphenols (Koak *et al.* 2010). Using mixture designs to improve optimization of nutraceuticals is an important focus of this dissertation.

3. Introduction to Internal and External Preference Mapping

Sensory scientists employ preference mapping as a tool to profile consumer preferences during product development and improvement. Perhaps the biggest advantage of preference mapping is its consideration of individual preferences, which are not considered when one looks at means from hedonic data. Indeed, utilizing mean hedonic scores alone may hide the preferences of specific segments (Meullenet *et al.* 2007), which may lead to developing a product that all consumers tolerate but in which no one is sufficiently satisfied. Perhaps the better strategy for product developers is to identify specific segments of consumers with similar expectations of a product category and seek to satisfy the requirements of that population segment.

Identifying the preferences of particular consumer segments is the goal behind preference mapping. There are two general approaches to reach this end: internal preference mapping (IPM) and external preference mapping (EPM). IPM utilizes consumer data, often overall impression scores, to profile consumer preferences of products in a multidimensional representation, while EPM relates consumer data to descriptive panel or instrumental data in order to define the product attributes that particular consumers prefer.

The representation of products and consumers obtained in IPM is generated through principal component analysis. Commonly, the researcher chooses to pretreat the data through centering based on individual means or scaling individuals to unit variance (Greenhoff and MacFie 1999).

Principal component analysis can either be performed on the covariance matrix or correlation matrix. Using the covariance matrix is the equivalent of mean centering of consumers. Scaling each consumer to unit variance is achieved by the use of the correlation matrix. Generally, not all principal components (i.e. preference dimensions) are used; thus the resulting configuration may only explain a low amount of variance and is considered just an approximation. Choosing to either use the covariance or correlation matrix may or may not change the interpretation of the resulting configuration of products. The decision is ultimately left to the researcher's best judgment.

External preference mapping employs a similar methodology, but in its case, the columns in the data matrix change from consumers to external data such as instrumental or descriptive sensory analyses. Perhaps the biggest criticism of this methodology is that the external data is not prioritized according to consumer preference, resulting in a representation that may include attributes that are not important to consumers (although some authors have attempted to improve the technique to address this). However, EPM is useful in many ways and remains a popular methodology.

The analysis of EPM is similar to that of IPM. Principal component analysis generates a multidimensional representation of the external data. Researchers may use standardized or centered data based on utilization of the correlation or covariance matrix respectively. Centered data may be more appropriate when the external data is expressed in the same units, while standardized data may be more appropriate when the data is expressed on different scales (Meullenet *et al.* 2007). After the external data is fitted, a polynomial model regresses the consumer liking scores in the sensory space. Many times after this analysis, the resulting configuration significantly fits only a fraction of consumers involved in the study. Strategies such as weighting more important attributes, first proposed by McEwan (1998), have been employed to increase the percentage of consumers represented in the space. Assigning weights based on the absolute correlation between attribute scores and the product scores (based on the first two principal components) is one approach to weighting. This strategy may not be beneficial (i.e. improve fit) in every model (Meullenet *et al.* 2007), but the technique remains a useful tool for sensory analysts.

In order to grasp the applications of preference mapping, perhaps the best strategy is to review case studies of particular examples. Here, we will review the use of the repertory grid method (RGM) coupled with generalized procrustes analysis (GPA) to profile consumer preferences of apples; Euclidian distance ideal point mapping (EDIPM), an attempt to improve standard preference mapping techniques through which the ideal sensory profiles of consumers are sought, to optimize a Muscadine grape juice blend; and EPM and IPM applied to juice blends and separately to lager beers to demonstrate the role of preference mapping in product development and improvement.

4. Case Studies of Preference Mapping

a. Repertory Grid Method and Generalized Procrustes Analysis

Kelly originated the RGM to elicit human perceptions of the constructs of their social world. Kelly (1955) defined construct as something that makes two things similar and in the same way dissimilar from a third thing. Olsen (1981) applied this technique to food products; he built on the method by instructing panelists to create their own scale to measure the intensity of each construct.

The method requires grouping samples into triads in which a sample appears once as a minimum, and one sample from each triad is moved to the next triad. The panelist is instructed to state the ways in which one sample is different from the other two, and these results are recorded. This is performed with each combination in the triad.

GPA, a technique in which products do not vary and thus a mathematical consensus is constructed to account for panelist differences, can be used to analyze the data collected from RGM. GPA is especially helpful because it can control three types of variation in sensory data through translation, reflection, and scaling. Translation eliminates the effects of panelists who misuse or misunderstood scaling intensity; there are many who consistently score attributes too high or too low. Reflection controls for different panelists using the same term in a different way. The process of reflection can make the created configurations more similar (Anonymous 1986). Finally, GPA can account for varying interpretations in how the scale should be used through isotropic scaling, which rescales individual scores to a more uniform scale, eliminating the bias that can be created from some panelists using a wide range of the scale and others only a small portion (Andani and MacFie 1998).

Andani and MacFie (1998) applied this method to consumer acceptability of apples. Of particular interest to the researchers was how people from different European countries perceived mealiness, a characteristic about which consumers often have negative connotations.

Five groups of 5 consumers from Denmark, UK, Spain, and Belgium (Flemish, French) were instructed to use RGM to describe Jonagold, Boskoop, and Cox apples. Their data was analyzed using GPA. The authors found that the consumers perceived differences in the samples similarly, and those from different countries generally perceived mealiness in a similar manner. Interestingly, the authors found that panelists used the descriptors differently. Danish consumers described Cox's Orange Pippen apples as mealy, while the British described these apples as coarse and spongy. The authors state that future work will establish similar vocabularies for the other consumer groups tested.

b. *Euclidian Distance Ideal Point Mapping*

Carroll (1972) originally introduced EPM, which has been applied to numerous consumer products since its introduction. Hedonic scores can be related to the arrangement of products in a sensory space using one of many fitting models. Among popular regression models is the quadratic surface model (Danzart 1998).

As mentioned in the introduction, criticisms of EPM include the lackluster fitting of consumers due to only using a few principal components. Researchers may only use the first two principal components because of the data overfitting that can occur when more complex, non-linear relationships are considered. The lackluster fitting of consumers can leave food companies making important decisions about the future and feasibility of a product based on a small sample size of consumers. Thus, the need for techniques such as EDIPM, which seek to improve the representation of the relationship between consumer liking and product attributes, is apparent.

EDIPM involves a series of steps. First, principal component analysis defines the sensory space. The point in which the correlation between hedonic scores and Euclidian distances to the products is maximized is defined as the ideal point of the individual. An acceptable region is selected around each individual's ideal point, and these acceptable regions are overlaid to identify the position of the ideal product. The sensory attributes are then projected in the map to determine the characteristics of the optimal product.

EDIPM was applied to Muscadine grape juice, a product whose increase in popularity shows promise in promoting the economies of the southeastern United States and improving human health through its nutraceutical properties. The cultivars included in the study were: Black Beauty, Ison, Carlos, Granny val, Nesbitt, Southern home, Summit and Supreme. Commercial red and commercial white samples were also included. The grape juices were subjected to consumer testing and descriptive analyses. The results were profiled using EDIPM and the quadratic response surface model (for purposes of comparison).

The first two principal components of the quadratic response surface model explained 47.4% and 24.7% of the data respectively. With three dimensions, 87.67% of the variability of the data was explained; however, only two dimensions were used. Musty was correlated with Muscadine flavor, and corresponding aromas and flavors were correlated. Sour and astringent juices were characterized as also possessing green/unripe flavor, while sweet juices were perceived as being high in floral and apple/pear flavors.

With this method, the optimal product location was near the Southern Home and Black Beauty varietals. At this location, 69% of the consumers were satisfied. The optimal solution was found to be 0.849, 0.044, and 0.195 of Black Beauty, Southern Home, and Ison, respectively.

In principal component analysis for EDIPM, consumers were variables and products were observations. The first two principal components explained 32.1% and 15.4% of the data respectively. When three dimensions were considered, 59.7% of the variance was explained, though the model was limited to two dimensions to allow for equal comparison with the response surface model.

The location found to maximize consumer liking was near Summit, Granny Val, and Carlos in which 42% of consumers found the product not significantly different from their ideal. Although this percentage seems low, the authors point out that the amount of consumers satisfied is dependent on the alpha level chosen to define the acceptable region for each consumer. The varietals chosen for barycenter calculations were Southern Home, Black Beauty, and Summit. These varietals were blended in proportions of 0.499, 0.480, and 0.021 respectively to create the EDIPM optimized product.

The validation study portion of the project showed that the two product optimizations were not significantly different from each other or the Granny Val varietal at alpha=0.05. The authors concluded that EDIPM was an alternative to RSM, especially when it was intended to solve some of the overfitting problems of the quadratic model. However, more exploration of EDIPM is needed (Meullenet *et al.* 2008).

In a review of ten vanilla ice creams, EDIPM was compared to external preference mapping derived from check-all-that-apply (CATA) consumer data and descriptive analysis. The authors found that the descriptive data and the consumer-created CATA profiles provided similar ideal product profiles, though the CATA counts were not as well fitting in the ideal product profile generated through EDIPM. The authors explain that this is not surprising because EDIPM is based on consumer preference data instead of product attributes (Dooley *et al.* 2010). CATA is a particularly interesting method because it is a hybrid between internal and external preference mapping. The maps are created through sensory attribute profiles, but consumers instead of trained panels generate the information.

c. Internal and External Preference Mapping

Perhaps the most practical use of preference mapping is the role it plays in product optimization. Scientists who were optimizing a white grape and tropical fruit juice blend utilized a 3x4 factorial design with 3 different tropical fruit concentrates (pineapple, banana, and passion fruit) and 4 different concentrations (1%,2%,3%,4%). Preliminary triangle testing showed that a

1% concentration was sufficient concentration for consumers to identify the juice component; thus, this concentration was used in consumer and descriptive analyses. A commercial pineapple juice was also included. The internal preference map illustrated that the commercial pineapple juice, followed by the passion fruit juice, were the most favored among consumers. When the quantitative characteristics were plotted, preference for the commercial pineapple product is explained by desire for pulp and pineapple flavor and reduced acceptance of sweetness and sweet fruit aroma. For descriptive analysis, principal component analysis was used to generate the relationships between the juices and the descriptors.

The authors of this study concluded that the 1% concentration was the optimal concentration for achieving consumer perception and limiting cost. They found that color, overall taste, acid taste, and acid fruit aroma were the most important considerations in developing a juice blend and that more work was needed to improve the juice blends before they were released to market (Serrano-Megias *et al.* 2005).

Preference mapping has been applied to many beverages in addition to juice. Guinard *et al.* (2001) utilized both external and internal preference in the profiling of lager beers; these authors also looked at the effect of blind vs. informed testing.

In this experiment, 170 users and likers of beer reviewed 24 different lagers falling in three major categories: domestic/ice, imported, and specialty. The testing was performed in 6 testing sessions over a two week period. Three of the tasting sessions were informed and 3 were uninformed. In the informed sessions, the consumers were told the brand of beer and the price of a six-pack. Descriptive analysis was also performed.

Two internal preference maps were created: one using the data from the informed sessions and one using the data from the uniformed sessions. The preference maps differed in the results obtained, and the authors concluded that information affected the hedonic ratings of the beers. Men and women in their 20s changed their preferences from the informed to uninformed sessions more than older consumers, which indicates that younger consumers may be more easily influenced by brand imaging.

The first two principal components used to generate the external preference map accounted for 87.4% of the variance. The first component was related to carbonation and desirable aromatic notes. The second component was related more to the possibility of undesirable attributes such as sulfury or grainy.

The authors concluded that hedonic ratings can be greatly influenced by informing consumers of what they are tasting (particularly for beer consumers in their 20s) and using numerous samples can generate clear preference maps (Guinard *et al.* 2001).

Preference mapping has many applications in sensory testing. The methods and examples reviewed in this section facilitate an understanding of the relationship between products and consumers. These ideas and strategies are helpful in the pursuit of the optimization of a nutraceutical-rich juice blend.

REFERENCES

1986. In *Statistical Procedures in Food Research*, (J.R. Piggott, ed.), Elsevier Applied Science Publishers Ltd., Amsterdam, Netherlands.

MonaVie. Monavie LLC. http://www.monavie.com/Web/US/en/index.dhtml (accessed August 29, 2010).

ALIGHOURCHI, H. and BARZEGAR, M. 2009. Some physicochemical characteristics and degradation kinetic of anthocyanin of reconstituted pomegranate juice during storage. J. Food Eng. *90*, 179-185, DOI: 10.1016/j.jfoodeng.2008.06.019.

ANDANI, Z. and MACFIE, H.J.H. 1998. Consumer preferences, expectations, and quality perceptions of dessert apples. Postharvest News and Information *9*, 39N-44N.

ANDERSEN, S., HARRISON, G.W., LAU, M.I. and RUTSTROM, E.E. 2008. Eliciting risk and time preferences. Econometrica *76*, 583-618.

ANDERSON, L.R. and MELLOR, J.M. 2008. Predicting health behaviors with an experimental measure of risk preference. J. Health Econ. *27*, 1260-1274, DOI: 10.1016/j.jhealeco.2008.05.011.

ARES, G., GIMENEZ, A. and GAMBARO, A. 2008. Uruguayan consumers' perception of functional foods. J. Sens. Stud. *23*, 614-630.

AYMOTO HASSIMOTTO, N.M., PINTO, M.D.S. and LAJOLO, F.M. 2008. Antioxidant Status in Humans after Consumption of Blackberry (Rubus fruticosus L.) Juices With and Without Defatted Milk. J. Agric. Food Chem. *56*, 11727-11733, DOI: 10.1021/jf8026149.

BAKER, S. 2007. Economics Interactive Tutorial Risk Aversion *2010*.

BARON, J., ASCH, D.A., FAGERLIN, A., JEPSON, C., LOEWENSTEIN, G., RIIS, J., STINEMAN, M.G. and UBEL, P.A. 2003. Effect of assessment method on the discrepancy between judgments of health disorders people have and do not have: A Web study. Medical Decision Making *23*, 422-434, DOI: 10.1177/0272989X03257277.

BARREIRO-HURLE, J., COLOMBO, S. and CANTOS-VILLAR, E. 2008. Is there a market for functional wines? Consumer preferences and willingness to pay for resveratrol-enriched red wine. Food Quality and Preference *19*, 360-371, DOI: 10.1016/j.foodqual.2007.11.004.

BOWDEN, G.T. 2004. Prevention of non-melanoma skin cancer by targeting ultraviolet-B-light signalling. Nature Reviews Cancer *4*, 23-35, DOI: 10.1038/nrc1253.

BROWN, J., CRANFIELD, J.A.L. and HENSON, S. 2005. Relating consumer willingness-to-pay for food safety to risk tolerance: An experimental approach. Canadian Journal of Agricultural Economics-Revue Canadienne D Agroeconomie *53*, 249-263.

CARROLL, J. 1972. Individual differences and multidimensional scaling. In *Multidimensional scaling: Theory and applications in the behavioral sciences*, Vol. 1, (R. Shepard, A. Romney and S. Nerlove, eds.) pp. 105-155, Seminar Press, New York.

CHANG, Y.C., HUANG, H.P., HSU, J.D., YANG, S.F. and WANG, C.J. 2005. Hibiscus anthocyanins rich extract-induced apoptotic cell death in human promyelocytic leukemia cells. Toxicol. Appl. Pharmacol. *205*, 201-212, DOI: 10.1016/j.taap.2004.10.014.

CHAPMAN, G. 1998. Sooner or later: the psychology of intertemporal choice. In *The Psychology of Learning and Motivation*, Vol. 38, (D.L. Medin, ed.) pp. 83 - 113.

CHAPMAN, G.B. 2003. Time Discounting of Health Outcomes. In *Time and Decision: Economic and Psychological Perspectives on Intertemporal Choice*, (G.A. Lowenstein, D. Read and R.F. Baumestier, eds.) pp. 395-418, Russell Sage Foundation, New York, New York.

CHAPMAN, G.B. 2000. Preferences for improving and declining sequences of health outcomes. J. Behav. Decis. Making *13*, 203-218.

CHAPMAN, G.B. 1996a. Expectations and preferences for sequences of health and money. Organ. Behav. Hum. Decis. Process. *67*, 59-75.

CHAPMAN, G.B. 1996b. Temporal discounting and utility for health and money. Journal of Experimental Psychology-Learning Memory and Cognition *22*, 771-791.

CHAPMAN, G.B., BREWER, N.T., COUPS, E.J., BROWNLEE, S., LEVENTHAL, H. and LEVENTHAL, E.A. 2001. Value for the future and preventive health behavior. Journal of Experimental Psychology-Applied *7*, 235-250, DOI: 10.1037//1076-898X.7.3.235.

CHAPMAN, G.B. and COUPS, E.J. 1999. Time preferences and preventive health behavior: Acceptance of the influenza vaccine. Medical Decision Making *19*, 307-314.

CHAPMAN, G.B. and ELSTEIN, A.S. 1995. Valuing the Future - Temporal Discounting of Health and Money. Medical Decision Making *15*, 373-386.

CHAPMAN, G.B. and WEBER, B.J. 2006. Decision biases in intertemporal choice and choice under uncertainty: Testing a common account. Mem. Cognit. *34*, 589-602.

CHESSON, H.W., LEICHLITER, J.S., ZIMET, G.D., ROSENTHAL, S.L., BERNSTEIN, D.I. and FIFE, K.H. 2006. Discount rates and risky sexual behaviors among teenagers and young adults. J. Risk Uncertainty *32*, 217-230, DOI: 10.1007/s11166-006-9520-1.

CHRISTENSEN-SZALANSKI, J.J.J. 1984. Discount Functions and the Measurement of Patients Values - Womens Decisions during Childbirth. Medical Decision Making *4*, 47-58.

COLLER, M. and WILLIAMS, M.B. 1999. Eliciting Individual Discount Rates. Experimental Economics *2*, 107-127.

CORNELL, J.A. 1981. Experiments with mixtures: designs, models, and the analysis of mixture data., Chichester, Sussex, UK; John Wiley & Sons. Price 19.80.

DAI, J., PATEL, J.D. and MUMPER, R.J. 2007. Characterization of blackberry extract and its antiproliferative and anti-inflammatory properties. J. Med. Food *10*, 258-265.

DANZART, M. Quadratic model in preference mapping.

DEL POZO-INSFRAN, D., PERCIVAL, S.S. and TALCOTT, S.T. 2006. Acai (Euterpe oleracea mart.) polyphenolics in their glycoside and aglycone forms induce apoptosis of HL-60 leukemia cells. J. Agric. Food Chem. *54*, 1222-1229, DOI: 10.1021/jf052132n.

DELIZA, R., MACFIE, H. and HEDDERLEY, D. 2003. Use of computer-generated images and conjoint analysis to investigate sensory expectations. J. Sens. Stud. *18*, 465-486, DOI: 10.1111/j.1745-459X.2003.tb00401.x.

DOHMEN, T., FALK, A., HUFFMAN, D., SUNDE, U., SCHUPP, J. and WAGNER, G.G. 2005. Individual risk attitudes: new evidence from a large, representative, experimentally-validated survey. IZA Discussion Paper No.1730 .

DOOLEY, L.M., THRELFALL, R.T. and MEULLENET, J. 2011. Using Mixture Designs to Create Red Wine Blends for Consumer Optimization. Am. J. Enol. Vitic. *62*, 394A-394A.

DOOLEY, L., LEE, Y. and MEULLENET, J. 2010. The application of check-all-that-apply (CATA) consumer profiling to preference mapping of vanilla ice cream and its comparison to classical external preference mapping. Food Quality and Preference *21*, 394-401, DOI: 10.1016/j.foodqual.2009.10.002.

ESSINK-BOT, M., STUIFBERGEN, M.C., MEERDING, W., LOOMAN, C.W.N., BONSEL, G.J. and VOTE GRP 2007. Individual differences in the use of the response scale determine valuations of hypothetical health states: an empirical study. Bmc Health Services Research *7*, 62, DOI: 10.1186/1472-6963-7-62.

FALSAPERLA, M., MORGIA, G., TARTARONE, A., ARDITO, R. and ROMANO, G. 2005. Support ellagic acid therapy in patients with hormone refractory prostate cancer (HRPC) on standard chemotherapy using vinorelbine and estramustine phosphate. Eur. Urol. *47*, 449-455, DOI: 10.1016/j.eururo.2004.12.001.

FELGINES, C., TEXIER, O., GARCIN, P., BESSON, C., LAMAISON, J. and SCALBERT, A. 2009. Tissue distribution of anthocyanins in rats fed a blackberry anthocyanin-enriched diet. Molecular Nutrition & Food Research *53*, 1098-1103, DOI: 10.1002/mnfr.200800323.

FRANKEL, E.N., BOSANEK, C.A., MEYER, A.S., SILLIMAN, K. and KIRK, L.L. 1998. Commercial grape juices inhibit the in vitro oxidation of human low-density lipoproteins. J. Agric. Food Chem. *46*, 834-838.

FREDERICK, S., LOEWENSTEIN, G. and O'DONOGHUE, T. 2002. Time discounting and time preference: A critical review. Journal of Economic Literature *40*, 351-401.

FRIEDRICH, J.E. and LEE, C.Y. 1998. Identification of non-anthocyanin phenolic compounds in sweet and sour cherries. IFT Annual Meeting Book of Abstracts .

GAO, L. and MAZZA, G. 1995. Characterization, Quantitation, and Distribution of Anthocyanins and Colorless Phenolics in Sweet Cherries. J. Agric. Food Chem. *43*, 343-346.

GARCIA-CLOSAS, R., GONZALEZ, C.A., AGUDO, A. and RIBOLI, E. 1999. Intake of specific carotenoids and flavonoids and the risk of gastric cancer in Spain. Cancer Causes & Control *10*, 71-75.

GIL, M.I., TOMAS-BARBERAN, F.A., HESS-PIERCE, B., HOLCROFT, D.M. and KADER, A.A. 2000. Antioxidant activity of pomegranate juice and its relationship with phenolic composition and processing. J. Agric. Food Chem. *48*, 4581-4589, DOI: 10.1021/jf000404a.

GOYARZU, F., MALIN, D.H., LAU, F.C., TAGLIALATELA, G., MOON, W.D., JENNINGS, R., MOY, E., MOY, D., LIPPOLD, S., SHUKITT-HALE, B. and JOSEPH, J.A. 2004. Blueberry supplemented diet: Effects on object recognition memory and nuclear factor-kappa B levels in aged rats. Nutr. Neurosci. *7*, 75-83, DOI: 10.1080/10284150410001710410.

GREENHOFF, K. and MACFIE, H.J.H. 1999. Preference mapping in practice. In *Measurement of food preferences*, (H.J.H. MacFie and D.M.H. Thomson, eds.), Aspen, Gaithersburg, MD.

GUINARD, J.X., UOTANI, B. and SCHLICH, P. 2001. Internal and external mapping of preferences for commercial lager beers: comparison of hedonic ratings by consumers blind versus with knowledge of brand and price. Food Quality and Preference *12*, 243-255.

GUO, C., WEI, J., YANG, J., XU, J., PANG, W. and JIANG, Y. 2008. Pomegranate juice is potentially better than apple juice in improving antioxidant function in elderly subjects. Nutr. Res. *28*, 72-77, DOI: 10.1016/j.nutres.2007.12.001.

GUYSE, J.L., KELLER, L.R. and EPPEL, T. 2002. Valuing environmental outcomes: Preferences for constant or improving sequences. Organ. Behav. Hum. Decis. Process. *87*, 253-277, DOI: 10.1006/obhd.2001.2965.

HAGER, T.J., HOWARD, L.R. and PRIOR, R.L. 2008. Processing and storage effects on monomeric anthocyanins, percent polymeric color, and antioxidant capacity of processed blackberry products. J. Agric. Food Chem. *56*, 689-695, DOI: 10.1021/jf071994g.

HARDISTY, D.J. and WEBER, E.U. 2009. Discounting Future Green: Money Versus the Environment. Journal of Experimental Psychology-General *138*, 329-340, DOI: 10.1037/a0016433.

HARRISON, G.W., LAU, M.I. and WILLIAMS, M.B. 2002. Estimating individual discount rates in Denmark: A field experiment. Am. Econ. Rev. *92*, 1606-1617.

HASSOUN, E.A., VODHANEL, J. and ABUSHABAN, A. 2004. The modulatory effects of ellagic acid and vitamin E succinate on TCDD-induced oxidative stress in different brain regions of rats after subchronic exposure. J. Biochem. Mol. Toxicol. *18*, 196-203.

HAYES, D.J., FOX, J.A. and SHOGREN, J.F. 2002. Experts and activists: how information affects the demand for food irradiation. Food Policy *27*, 185-193.

HEBER, D. 2008. Multitargeted therapy of cancer by ellagitannins. Cancer Lett. *269*, 262-268, DOI: 10.1016/j.canlet.2008.03.043.

HERSCH, J. and VISCUSI, W.K. 1990. Cigarette-Smoking, Seat-Belt Use, and Differences in Wage-Risk Tradeoffs. J. Hum. Resour. *25*, 202-227.

JACOB, R.A., SPINOZZI, G.M., SIMON, V.A., KELLEY, D.S., PRIOR, R.L., HESS-PIERCE, B. and KADER, A.A. 2003. Consumption of cherries lowers plasma urate in healthy women. J. Nutr. *133*, 1826-1829.

JENSEN, G.S., WU, X., PATTERSON, K.M., BARNES, J., CARTER, S.G., SCHERWITZ, L., BEAMAN, R., ENDRES, J.R. and SCHAUSS, A.G. 2008. In vitro and in vivo antioxidant and anti-inflammatory capacities of an antioxidant-rich fruit and berry juice blend. Results of a pilot and randomized, double-blinded, placebo-controlled, crossover study. J. Agric. Food Chem. *56*, 8326-8333, DOI: 10.1021/jf8016157.

JOSEPH, J.A., SHUKITT-HALE, B., DENISOVA, N.A., BIELINSKI, D., MARTIN, A., MCEWEN, J.J. and BICKFORD, P.C. 1999. Reversals of age-related declines in neuronal signal transduction, cognitive, and motor behavioral deficits with blueberry, spinach, or strawberry dietary supplementation. Journal of Neuroscience *19*, 8114-8121.

JOSHIPURA, K.J., HU, F.B., MANSON, J.E., STAMPFER, M.J., RIMM, E.B., SPEIZER, F.E., COLDITZ, G., ASCHERIO, A., ROSNER, B., SPIEGELMAN, D. and WILLETT, W.C. 2001. The effect of fruit and vegetable intake on risk for coronary heart disease. Ann. Intern. Med. *134,* 1106-1114.

KALT, W., BLUMBERG, J.B., MCDONALD, J.E., VINQVIST-TYMCHUK, M.R., FILLMORE, S.A.E., GRAF, B.A., O'LEARY, J.M. and MILBURY, P.E. 2008. Identification of anthocyanins in the liver, eye, and brain of blueberry-fed pigs. J. Agric. Food Chem. *56*, 705-712, DOI: 10.1021/jf071998l.

KATSUBE, N., IWASHITA, K., TSUSHIDA, T., YAMAKI, K. and KOBORI, M. 2003. Induction of apoptosis in cancer cells by bilberry (Vaccinium myrtillus) and the anthocyanins. J. Agric. Food Chem. *51*, 68-75, DOI: 10.1021/jf025781x.

KELLY, G.A. 1955. The psychology of personal constructs. Norton, New York.

KHWAJA, A., SILVERMAN, D. and SLOAN, F. 2007. Time preference, time discounting, and smoking decisions. J. Health Econ. *26*, 927-949, DOI: 10.1016/j.jhealeco.2007.02.004.

KIM, D.O., HEO, H.J., KIM, Y.J., YANG, H.S. and LEE, C.Y. 2005. Sweet and sour cherry phenolics and their protective effects on neuronal cells. J. Agric. Food Chem. *53*, 9921-9927, DOI: 10.1021/jf0518599.

KIRBY, K.N. and MARAKOVIC, N.N. 1995. Modeling Myopic Decisions - Evidence for Hyperbolic Delay-Discounting Within-Subjects and Amounts. Organ. Behav. Hum. Decis. Process. *64*, 22-30.

KNEKT, P., KUMPULAINEN, J., JARVINEN, R., RISSANEN, H., HELIOVAARA, M., REUNANEN, A., HAKULINEN, T. and AROMAA, A. 2002. Flavonoid intake and risk of chronic diseases. Am. J. Clin. Nutr. *76*, 560-568.

KOAK, J.H., KANG, B.S., HAHM, Y.T., PARK, C.S., BAIK, M.Y. and KIM, B.Y. 2010. Blending of Different Domestic Grape Wines Using Mixture Design and Optimization Technique. Food Science and Biotechnology *19*, 1011-1018, DOI: 10.1007/s10068-010-0142-7.

KRIS-ETHERTON, P.M., HECKER, K.D., BONANOME, A., COVAL, S.M., BINKOSKI, A.E., HILPERT, K.F., GRIEL, A.E. and ETHERTON, T.D. 2002. Bioactive compounds in foods: Their role in the prevention of cardiovascular disease and cancer. Am. J. Med. *113*, 71-88.

KUHFELD, W.F. 2010. Marketing Research Methods in SAS. SAS Institute Inc., Cary, N.C.

KUMAR, S.B., RAVI, R. and SARASWATHI, G. 2010. Optimization of Fruit Punch Using Mixture Design. J. Food Sci. *75*, S1-S7, DOI: 10.1111/j.1750-3841.2009.01379.x.

LANSKY, E.P., HARRISON, G., FROOM, P. and JIANG, W.G. 2005a. Pomegranate (Punica granatum) pure chemicals show possible synergistic inhibition of human PC-3 prostate cancer cell invasion across Matrigel (TM). Invest. New Drugs *23*, 121-122.

LANSKY, E.P., JIANG, W.G., MO, H.B., BRAVO, L., FROOM, P., YU, W.P., HARRIS, N.M., NEEMAN, I. and CAMPBELL, M.J. 2005b. Possible synergistic prostate cancer suppression by anatomically discrete pomegranate fractions. Invest. New Drugs *23*, 11-20.

LE MARCHAND, L., MURPHY, S.P., HANKIN, J.H., WILKENS, L.R. and KOLONEL, L.N. 2000. Intake of flavonoids and lung cancer. J. Natl. Cancer Inst. *92*, 154-160.

LEE, K.H. and HATCHER, C.B. 2001. Willingness to pay for information: An analyst's guide. J. Consumer Aff. *35*, 120-140.

LELAND, J.W. 2002. Similarity judgments and anomalies in intertemporal choice. Econ. Inq. *40*, 574-581.

LIEU, T.A., RAY, G.T., ORTEGA-SANCHEZ, I.R., KLEINMAN, K., RUSINAK, D. and PROSSER, L.A. 2009. Willingness to Pay for a QALY Based on Community Member and Patient Preferences for Temporary Health States Associated with Herpes Zoster. Pharmacoeconomics *27*, 1005-1016.

LOEWENSTEIN, G. and PRELEC, D. 1992. Anomalies in Intertemporal Choice - Evidence and an Interpretation. Q. J. Econ. *107*, 573-597.

LUND, C.M., JAEGER, S.R., AMOS, R.L., BROOKFIELD, P. and HARKER, F.R. 2006. Tradeoffs between emotional and sensory perceptions of freshness influence the price consumers will pay for apples: Results from an experimental market. Postharvest Biol. Technol. *41*, 172-180, DOI: 10.1016/j.postharvbio.2006.03.011.

MA, L., FEUGANG, J.M., KONARSKI, P., WANG, J., LU, J.Z., FU, S.J., MA, B.L., TIAN, B.Q., ZOU, C.P. and WANG, Z.P. 2006. Growth inhibitory effects of quercetin on bladder cancer cell. Frontiers in Bioscience *11*, 2275-2285.

MAYNARD, L.J. and FRANKLIN, S.T. 2003. Functional foods as a value-added strategy: The commercial potential of "cancer-fighting" dairy products. Review of Agricultural Economics *25*, 316-331.

MCEWAN, J.A. 1998. Cluster Analysis and Preference Mapping *Review No. 12*.

MEILGAARD, M., SEVILLE, G.V. and CARR, B.T. 2007. Sensory Evaluation Techniques, Fourth ed. . CRC Press, U.S.A.

MERTENS-TALCOTT, S.U. and PERCIVAL, S.S. 2005. Ellagic acid and quercetin interact synergistically with resveratrol in the induction of apoptosis and cause transient cell cycle arrest in human leukemia cells. Cancer Lett. *218*, 141-151, DOI: 10.1016/j.canlet.2004.06.007.

MERTENS-TALCOTT, S.U., RIOS, J., JILMA-STOHLAWETZ, P., PACHECO-PALENCIA, L.A., MEIBOHM, B., TALCOTT, S.T. and DERENDORF, H. 2008. Pharmacokinetics of anthocyanins and antioxidant effects after the consumption of anthocyanin-rich acai juice and pulp (Euterpe oleracea Mart.) in human healthy volunteers. J. Agric. Food Chem. *56*, 7796-7802, DOI: 10.1021/jf8007037.

MEULLENET, J.-., XIONG, R. and FINDLAY, C.J. 2007. Multivariate and probabilistic analyses of sensory science problems. IFT Press and Blackwell Publishing, U.S.A.

MEULLENET, J.-F., LOVELY, C., THRELFALL, R., MORRIS, J.R. and STRIEGLER, R.K. 2008. An ideal point density plot method for determining an optimal sensory profile for Muscadine grape juice. Food Quality and Preference *19*, 210-219, DOI: 10.1016/j.foodqual.2007.06.011.

MORAND, C., CRESPY, V., MANACH, C., BESSON, C., DEMIGNE, C. and REMESY, C. 1998. Plasma metabolites of quercetin and their antioxidant properties. American Journal of Physiology-Regulatory Integrative and Comparative Physiology *275*, R212-R219.

MOSKOWITZ, H.R. 1980. Psychometric Evaluation of Food. Journal of Food Service Systems *1*, 149-167.

MUNOZ-ESPADA, A.C., WOOD, K.V., BORDELON, B. and WATKINS, B.A. 2004. Anthocyanin quantification and radical scavenging capacity of Concord, Norton, and Marechal Foch grapes and wines. J. Agric. Food Chem. *52*, 6779-6786, DOI: 10.1021/jf040087y.

NAPOLITANO, F., PACELLI, C., GIROLAMI, A. and BRAGHIERI, A. 2008. Effect of information about animal welfare on consumer willingness to pay for yogurt. J. Dairy Sci. *91*, 910-917, DOI: 10.3168/jds.2007-0709.

NAYGA, R.M. 2009. Introduction to Economic Experiments: Applications to Marketing. Class Lecture.

NAYGA, R.M., JR., WOODWARD, R. and AIEW, W. 2006. Willingness to pay for reduced risk of foodborne illness: A nonhypothetical field experiment. Canadian Journal of Agricultural Economics-Revue Canadienne D Agroeconomie *54*, 461-475.

O'BYRNE, D.J., DEVARAJ, S., GRUNDY, S.M. and JIALAL, I. 2002. Comparison of the antioxidant effects of Concord grape juice flavonoids and alpha-tocopherol on markers of oxidative stress in healthy adults. Am. J. Clin. Nutr. *76*, 1367-1374.

OLSEN, J.C. 1981. The importance of cognitive processes and structures for existing knowledge understanding food acceptance. In *Criteria of food acceptance*, (J. Solms and R.L. Hall, eds.), Forster, Zurich, Switzerland.

OUPADISSAKOON, G. and MEULLENET, J.F. July 27, 2009. Performance assessment of the 9-pt verbal hedonic and ideal point line scales.

PACHECO-PALENCIA, L.A., HAWKEN, P. and TALCOTT, S.T. 2007. Phytochemical, antioxidant and pigment stability of acai (Euterpe oleracea Mart.) as affected by clarification, ascorbic acid fortification and storage. Food Res. Int. *40*, 620-628, DOI: 10.1016/j.foodres.2006.11.006.

PACHECO-PALENCIA, L.A., NORATTO, G., HINGORANI, L., TALCOTT, S.T. and MERTENS-TALCOTT, S.U. 2008. Protective effects of standardized pomegranate (Punica granatum L.) polyphenolic extract in ultraviolet-irradiated human skin fibroblasts. J. Agric. Food Chem. *56*, 8434-8441, DOI: 10.1021/jf8005307.

PERCOCO, M. and NIJKAMP, P. 2009. Estimating individual rates of discount: a meta-analysis. Applied Economics Letters *16*, 1235-1239, DOI: 10.1080/13504850701367189.

PERYAM, D.R. and PILGRIM, F.J. 1957. The Hedonic Scale Method of Measuring Food Preference. Food Technol. *11*, 32-32.

PRELEC, D. and LOEWENSTEIN, G. 1991a. Decision-Making Over Time and Under Uncertainty - a Common Approach. Management Science *37*, 770-786.

PRELEC, D. and LOEWENSTEIN, G. 1991b. Decision-Making Over Time and Under Uncertainty - a Common Approach. Management Science *37*, 770-786.

READ, D., FREDERICK, S., ORSEL, B. and RAHMAN, J. 2005. Four score and seven years from now: The date/delay effect in temporal discounting. Management Science *51*, 1326-1335, DOI: 10.1287/mnsc.1050.0412.

RICE-EVANS, C.A., MILLER, N.J., BOLWELL, G.P., BRAMLEY, P.M. and PRIDHAM, J.B. 1995. The Relative Antioxidant Activities of Plant-Derived Polyphenolic Flavonoids. Free Radic. Res. *22*, 375-383.

RICE-EVANS, C.A., MILLER, N.J. and PAGANGA, G. 1996. Structure-antioxidant activity relationships of flavonoids and phenolic acids. Free Radical Biology and Medicine *20*, 933-956.

RUBINSTEIN, A. 2003. "Economics and psychology"? The case of hyperbolic discounting. International Economic Review *44*, 1207-1216.

SCHMIDT, D.R. and SOBOTA, A.E. 1988. An Examination of the Anti-Adherence Activity of Cranberry Juice on Urinary and Nonurinary Bacterial Isolates. Microbios *55*, 173-181.

SEERAM, N.P. 2006. Berries. In *Nutritional Oncology*, (D. Heber, G. Blackburn, V.L.W. Go and J. Milner, eds.) pp. 615-625, Academic Press, London.

SEERAM, N.P., ADAMS, L.S., ZHANG, Y., LEE, R., SAND, D., SCHEULLER, H.S. and HEBER, D. 2006. Blackberry, black raspberry, blueberry, cranberry, red raspberry, and strawberry extracts inhibit growth and stimulate apoptosis of human cancer cells in vitro. J. Agric. Food Chem. *54*, 9329-9339, DOI: 10.1021/jf061750g.

SERRANO-MEGIAS, M., PEREZ-LOPEZ, A.J., NUNEZ-DELICADO, E., BELTRAN, F. and LOPEZ-NICOLAS, J.M. 2005. Optimization of tropical juice composition for the Spanish market. J. Food Sci. *70*, S28-S33.

SHANMUGAM, K.R. 2006. Rate of time preference and the quantity adjusted value of life in India. Environ. Dev. Econ. *11*, 569-583, DOI: 10.1017/S1355770X06003135.

SHI, H., NOGUCHI, N. and NIKI, E. 2001. Introducing natural antioxidants. In *Antioxidants in food*, (J. Pokorny, N. Yanishlieva and M. Gordon, eds.) pp. 147-158, Woodhead Publishing Limited, Cambridge.

SHUKITT-HALE, B., CAREY, A.N., JENKINS, D., RABIN, B.M. and JOSEPH, J.A. 2007. Beneficial effects of fruit extracts on neuronal function and behavior in a rodent model of accelerated aging. Neurobiol. Aging *28*, 1187-1194, DOI: 10.1016/j.neurobiolaging.2006.05.031.

SHUKITT-HALE, B., CHENG, V. and JOSEPH, J.A. 2009. Effects of blackberries on motor and cognitive function in aged rats. Nutr. Neurosci. *12*, 135-140, DOI: 10.1179/147683009X423292.

SHUKITT-HALE, B., LAU, F.C. and JOSEPH, J.A. 2008. Berry fruit supplementation and the aging brain. J. Agric. Food Chem. *56*, 636-641, DOI: 10.1021/jf072505f.

SIEGRIST, M., STAMPFLI, N. and KASTENHOLZ, H. 2008. Consumers' willingness to buy functional foods. The influence of carrier, benefit and trust. Appetite *51*, 526-529, DOI: 10.1016/j.appet.2008.04.003.

SOBOTA, A.E. 1984. Inhibition of Bacterial Adherence by Cranberry Juice - Potential use for the Treatment of Urinary-Tract Infections. J. Urol. *131*, 1013-1016.

STOTHERS, L. 2002. A randomized trial to evaluate effectiveness and cost effectiveness of naturopathic cranberry products as prophylaxis against urinary tract infection in women. Can. J. Urol. *9*, 1558-1562.

SYED, D.N., AFAQ, F. and MUKHTAR, H. 2007. Pomegranate derived products for cancer chemoprevention. Semin. Cancer Biol. *17*, 377-385, DOI: 10.1016/j.semcancer.2007.05.004.

TUERK, G., SOENMEZ, M., AYDIN, M., YUECE, A., GUER, S., YUEKSEL, M., AKSU, E.H. and AKSOY, H. 2008. Effects of pomegranate juice consumption on sperm quality, spermatogenic cell density, antioxidant activity and testosterone level in male rats. Clinical Nutrition *27*, 289-296, DOI: 10.1016/j.clnu.2007.12.006.

TUORILA, H. and CARDELLO, A.V. 2002. Consumer responses to an off-flavor in juice in the presence of specific health claims. Food Quality and Preference *13*, 561-569.

USENIK, V., FABCIC, J. and STAMPAR, F. 2008. Sugars, organic acids, phenolic composition and antioxidant activity of sweet cherry (Prunus avium L.). Food Chem. *107*, 185-192, DOI: 10.1016/j.foodchem.2007.08.004.

VAN DER POL, M. and CAIRNS, J. 2008. Comparison of two methods of eliciting time preference for future health states. Soc. Sci. Med. *67*, 883-889, DOI: 10.1016/j.socscimed.2008.05.011.

VEBERIC, R. and STAMPAR, F. 2005. Selected polyphenols in fruits of different cultivars of genus Prunus. Phyton-Annales Rei Botanicae *45*, 375-383.

VICKREY, W. 1961. Counterspeculation, Auctions, and Competitive Sealed Tenders. J. Finance *16*, 8-37.

WANG, H.B., NAIR, M.G., IEZZONI, A.F., STRASBURG, G.M., BOOREN, A.M. and GRAY, J.I. 1997. Quantification and characterization of anthocyanins in Balaton tart cherries. J. Agric. Food Chem. *45*, 2556-2560.

WANG, H.B., NAIR, M.G., STRASBURG, G.M., BOOREN, A.M. and GRAY, J.I. 1999a. Antioxidant polyphenols from tart cherries (Prunus cerasus). J. Agric. Food Chem. *47*, 840-844.

WANG, I.K., LIN-SHIAU, S.Y. and LIN, J.K. 1999b. Induction of apoptosis by apigenin and related flavonoids through cytochrome c release and activation of caspase-9 and caspase-3 in leukaemia HL-60 cells. Eur. J. Cancer *35*, 1517-1525.

BIBLIOGRPAHY

DOOLEY, L. 2011. Consumer understanding and nutraceutical composition of red table wine blends. Ph.D. Dissertation, University of Arkansas.

CHAPTER 3

Sensory, Compositional, and Color Properties of Nutraceutical-Rich Juice Blends

Lydia J. R. Lawless, Renee T. Threlfall, Luke R. Howard, Jean-François Meullenet

Accepted to the American Journal of Enology and Viticulture

ACKNOWLEDGMENTS

Funding for this study was provided by a USDA-NIFA-SCRI grant. The authors would like to acknowledge Dr. Gary Main, Cindi M. Brownmiller, and Tonya S.P. Tokar for their support of this project.

ABSTRACT

Phytochemical-rich fruits such as grapes, blueberries, and blackberries may be antioxidative, anticarcinogenic, and antimutagenic, which makes the juices of these fruits prime candidates for the nutraceutical market. Understanding consumer acceptance and compositional, color, and descriptive sensory changes during storage is crucial to the success of nutraceutical juices. Juices (blackberry, blueberry, and Concord grape) were blended according to the ABCD mixture design (3 primary juices, 3 binary blends, and 4 tertiary blends). Prior to storage, a trained descriptive panel (n = 8) determined Concord-containing blends were generally sweeter, less bitter, less astringent, and less sour than blackberry- or blueberry-containing blends. When relating compositional, color, and descriptive sensory characteristics, sweetness was inversely correlated to total phenolics (r = -0.88), total anthocyanins (r = -0.75), color density (r = -0.84), and astringency (r = -0.92) and positively correlated with soluble solids (r =0 .92) and polymeric color (r = 0.78). Consumers (n = 108) evaluated overall liking on the 9-point verbal hedonic scale. Average liking scores were high for 100% Concord juice (7.79), moderate for 100% blueberry juice (5.47), and low for 100% blackberry juice (2.95). Consumer acceptance was driven by soluble solids, total anthocyanins, purple color, red color, astringency, sweetness, and grape flavor. Compositional, color, and descriptive sensory changes were tracked during 200 days storage at 2°C and 21°C. Prior to storage, 100% blueberry juice had the highest total anthocyanins (67 mg/100mL), 100% blackberry juice had the highest total phenolics (249

mg/100mL), and 100% Concord juice had the highest polymeric color (23%). During storage, polymeric color increased as total anthocyanins decreased at 2°C and 21°C. Blending juices balanced nutraceutical enhancement and maintenance of consumer acceptance.

INTERPRETIVE ABSTRACT

Fruits such as blackberries, blueberries, and Concord grapes are high in compounds that may help prevent cancer and protect against aging, which appeals to health-conscious consumers. Potential healthy compounds include total phenolics and total anthocyanins; higher levels of these components are often found in dark-pigmented juices. Understanding what consumers like about healthy fruit juices and what happens to potentially healthy compounds during storage is crucial to the marketability of juice blends. Ten juice treatments were created (3 single juices, 3 blends of 2 juices, and 4 blends of 3 juices). Prior to storage, a trained descriptive sensory panel (n = 8) determined Concord-containing blends were generally sweeter, less bitter, less astringent, and less sour than blackberry- or blueberry-containing blends. When relating compositional, color, and descriptive sensory characteristics, sweetness increased as total phenolics, total anthocyanins, color density, and astringency (i.e. drying sensation in the mouth) decreased and as soluble solids and polymeric color increased. Consumers' overall liking scores were high for 100% Concord juice, moderate for 100% blueberry juice, and low for 100% blackberry juice. Consumer acceptance was driven by sweetness (soluble solids level), total monomeric anthocyanins, purple color, red color, astringency, and grape flavor. Changes to composition, color, and descriptive sensory characteristics were measured during 200 days storage at 2°C and 21°C. Prior to storage, 100% blueberry juice was highest in total anthocyanins, 100% Concord juice was highest in polymeric color (i.e indication of how many procyanidins have attached to anthocyanins), and 100% blackberry juice was highest in total phenolics. During storage, polymeric color increased as total anthocyanins decreased at 2°C and 21°C. Blending juices was shown to enhance concentration of potentially healthy compounds while maintaining consumer overall liking.

Keywords: blueberry, blackberry, grape; juice, sensory, nutraceutical

INTRODUCTION

Many fruits such as blackberries (*Rubus*), blueberries (*Vaccinium*), and Concord grapes (*Vitis labruscana*) contain flavonoids. Flavonoids possess potential health benefits that include antioxidant, anticarcinogenic and anti-inflammatory effects *in vitro* and neurologically protective effects *in vivo* (Bravo 1998, Cho et al. 2004, Shukitt-Hale et al. 2009, Joseph et al. 1999). These dark-pigmented fruits can be used to create products with nutraceutical consumer appeal.

The nutraceutical properties of these fruits are generally studied without consideration of sensory descriptive properties and consumer acceptance. Tandem consideration of nutraceutical and sensory properties is crucial because some flavonoids can impart bitterness or astringency, which may affect sensory attribute intensities and possibly decrease consumer acceptance (Drewnowski and Gomez-Carneros 2000, Herrmann 1992, Robichaud and Noble 1990). Juice blending has previously been shown to improve consumer acceptance while maintaining health properties (Vazquez-Araujo et al. 2010). Consumer acceptance is crucial for long-term marketplace success of nutraceutical-rich products.

Consumer acceptance can be assessed with affective sensory testing, in which large sample sizes of consumers are recruited and asked to indicate their liking of product(s). Descriptive sensory testing with trained panelists objectively determines sensory attribute intensities. Statistical techniques such as partial least squares regression are utilized to relate affective data with descriptive or instrumentally-measured color or compositional data and establish how compositional, color, and descriptive properties influence overall liking (Meullenet et al. 2007).

Fruit juice is a good candidate for the nutraceutical market because consumers are more willing to accept nutraceutical claims if the base product has a healthy connotation (Siegrist et al. 2008). Additionally, juice is a popular consumer product that can easily be consumed on-the-go for convenience (Gracia et al. 2011). However, storage time and temperature affect the stability of flavonoids in fruits and fruit products (Igual et al. 2011, Piljac-Zegarac and Samec 2011). Understanding how storage conditions influence nutraceutical value in flavonoid-rich fruit juices is essential because fruit juice is often shelf-stable and not consumed immediately. The objectives of this study were to 1) establish and relate initial descriptive sensory, compositional, and color properties of juice and juice blends, 2) evaluate and identify drivers of consumer acceptance of juice and juice blends, and 3) assess descriptive sensory and compositional changes of juice and juice blends during 200 days storage at 2°C and 21°C.

MATERIALS AND METHODS

Fruit. Juice was produced from fresh, locally-grown fruit, Natchez blackberries (*Rubus L. subgenus Rubus Watson*) and Bluetta blueberries (*Vaccinium corymbosum).* In addition, Concord (*Vitis labruscana* Bailey) frozen grape concentrate was reconstituted to 15% soluble solids prior to processing. Concord grape concentrate was used because fresh grapes were not available during blackberry and blueberry harvest.

Juice processing, blending and bottling. Juice was processed at the University of Arkansas Enology Research Laboratory and Pilot Plant, Fayetteville. Juice production methods were similar to those used in previous studies (Hager et al. 2008, Brownmiller et al. 2008) that simulate commercial production. The blackberries (127 kg) and blueberries (135 kg) were frozen at -2°C prior to processing and then poured directly into a stainless steel steam kettle for processing into juice. While stirring continuously, the must was heated to 95°C, held for 3 minutes, and cooled to 40°C by cool water circulation through the exterior of the kettle. Pectinex 3XL enzyme (Novozyme Corp., Bagsvaerd, Denmark) was added to the must at a rate of 0.0827 mL/kg. The must was held for 1 hour and then tested for depectinization with a negative alcohol precipitation test.

The must was pressed in a 70-L Enrossi bladder press (Enoagricol Rossi s.r.l., Calzolaro, Italy) using additional screens and press cloths, collected in carboys, and cold settled. After racking, the juice was filtered with the Buon Vino Flojet (Model T2913, Canada) with 9 to 10 micron filter. The Concord grape juice concentrate was reconstituted to 15% total soluble solids with deioinized water and filtered. In order to maintain as natural a product as possible, sugar and acid levels of the blackberry, blueberry and Concord juice and juice blends were not adjusted or balanced.

An ABCD mixture design of three components was used to formulate the blending treatments (Figure 1). Within each blending treatment, x-variables were expressed as percentages and summed to 100%. Prior to blending, each type of juice was combined into one lot. Juice was blended volumetrically resulting in 10 treatments: three single-component juices, 100% blackberry (Blk), 100% blueberry (Blu), and 100% Concord (Con), three binary blends, 50%Blu+50%Blk, 50%Blu+50%Con, 50%Blk+50%Con, and four tertiary blends 17%Blu+17%Blk+67%Con, 17%Blu+67%Blk+17%Con, 67%Blu+17%Blk+17%Con, 33%Blu+33%Blk+33%Con. The juice was bottled into either 125 mL, 375 mL, or 3.8 L glass jars and then steam pasteurized to 90°C. Pasteurization time ranged from 10 to 30 min depending on container volume, but jars were pasteurized by volume size. The jars were removed, capped, and placed on their sides to cool. Treatments were stored at 21°C and 2°C for 200 days.

Compositional and color analysis. Prior to analysis, juices were equilibrated to 21°C and then centrifuged 13,250g for 10 min. Juices were diluted as needed for analysis.

Soluble solids, pH, and titratable acidity. An Accumet Basic pH meter determined juice pH (Fischer Scientific, Denver Instrument Company, Bohemia, NY). Titratable acidity (expressed as tartaric acid in g/L) was measured by placing 5 mL of juice into 125 mL of degassed, deionized water and titrating with 0.1 N sodium hydroxide to an endpoint of pH 8.2 (Iland et al. 2004). Total soluble solids (%) was measured with a Bausch & Lomb Abbe Mark II refractometer (Scientific Instrument, Keene, NH).

Color Density. An 8452A photodiode array spectrophotometer (Hewlett-Packard, Palo, Alto, CA) was used to measure color density (420 + 510 nm).

Total phenolics. Total phenolics was measured using the Folin-Ciocalteu assay (Slinkard and Singleton 1977) with a gallic acid standard and a consistent standard curve based on serial dilutions. Absorbencies were measured at 760 nm, and results were expressed as gallic acid equivalents (GAE).

Oxygen radical absorbance capacity. Oxygen radical absorbance capacity (ORAC) was determined on a dual pump BMG Fluostar Optima plate reader (Durham, NC). Results were generated from evaluating the area under the curve for test samples as compared to a Trolox standard and developing a standard curve based on dilutions (final concentrations 6.25, 12.5, 25, 50 µM) of Trolox. ORAC values were calculated using regression to TE concentration.

*Total monomeric anthocyanins***.** Anthocyanins were determined with the pH differential method (Giusti and Wrolstad 2004). Samples were added to buffered solutions at pH=1.0 (potassium chloride) and pH = 4.5 (sodium acetate). At pH = 1.0, the colored anthocyanin form, oxonium, predominates. At pH = 4.5, the colorless anthocyanin form, hemiketal, predominates. Absorbance was measured at 510 and 700 nm and calculated according to the equation, $A = (A_{510}-A_{700})_{pH=1.0} - (A_{510}-A_{700})_{pH=4.5}$. Anthocyanin pigment concentration was calculated with molar extinction coefficient (26,900) and molecular weight (449.2) for cyanidin-3-glucoside, according to the equation, Concentration=(Absorbance* molecular weight* dilution factor*1000)/(extinction coefficient *1).

Polymeric color. Percent polymeric color was measured according to the method of Giusti and Wrolstad (2004). The added potassium metabisulfite bleached monomeric anthocyanins as the polymers remain colored. Absorbencies of samples were taken at 420, 510, and 700 nm spectrophotometrically.

Sensory descriptive analysis. Sensory analysis was performed at the Sensory and Consumer Research Center at the University of Arkansas, Fayetteville. Eight Sensory Spectrum® trained panelists evaluated the juices initially and during storage. Panelists had a minimum of 7 years experience evaluating various products six hours per week.

Prior to evaluation, panelists sampled and discussed commercial blackberry, blueberry, and Concord grape juices and determined lexicon terms during orientation. Samples were labeled with random three-digit codes and served monadically. A complete randomized block design balanced for sample position order was used to prevent presentation order bias and sensory fatigue from affecting evaluations.

The descriptive panel indicated the intensity of basic tastes (sweet, sour, bitter), feeling factors (metallic, astringency), and aromatics of each juice (grape note, blueberry note, blackberry note, green unripe, musty dirty, burnt, overripe fruit, metallic, caramelized, grape skin, fermented) on a 15-point scale. Panelists evaluated color with the aid of standards developed with Assorted Food Color & Egg Dye (McCormick & Company, Inc., Baltimore, MD) that were used throughout the study.

Consumer evaluations. The Sensory and Consumer Research Center recruited consumers (n = 108) based on consumption of fruit juice (3 times per week) and liking of blueberries, blackberries, and Concord grapes. Consumers evaluated overall liking on the 9-point verbal hedonic scale for all 10 juice treatments over a two day period (5 samples/day) in isolated tasting booths. A complete block design was used to assign presentation order to each panelist to prevent serving order bias. Consumer responses were collected via computer software (Compusense *five*, release 4.8, Compusense Inc., Guelph, Ontario, Canada). The consumers evaluated juice stored at 2°C for 96 days.

Experimental design. For compositional and color analysis, the 10 juice treatments were evaluated at 0, 34, 68, 102, and 200 days during storage at 2° and 21°C in triplicate. For descriptive sensory analysis, the 10 juice treatments were evaluated at the same time points during storage at the same temperatures. Descriptive panelists did not perform replications in order to minimize sensory fatigue. Consumers (n = 108) evaluated 10 blending treatments determined by the ABCD mixture design over two days (5 samples/day) according to a design balanced for position order.

Statistical analysis. Compositional, color, and sensory data were analyzed with ANOVA (JMP® software ver. 8.0.2, Cary, NC). Consumer and descriptive sensory data were analyzed with two-way ANOVA with panelist as a random effect and blending treatment as a fixed effect. Mean separation was performed with Tukey's HSD at $\alpha = 0.05$. The relationships among descriptive sensory, compositional, and color data were assessed through Pearson's correlations. Two separate partial least squares regression-1 (PLSR) models were performed on standardized data. Both models utilized mean overall liking as the response. For one model, compositional properties were x-variables, and for the other model, descriptive properties were x-variables (Unscrambler X version 10.1, CAMO Software Inc., Woodbridge, NJ). Effects of storage on compositional properties were assessed by temperature with two factors (time and blending treatment) plus first-order interaction effect ANOVA models. Tukey's HSD was calculated for significant effects. Effects of storage on descriptive sensory data were examined through principal component analysis (Unscrambler X ver. 10.1, CAMO Software Inc., Woodbridge, NJ).

RESULTS AND DISCUSSION

Establish and relate initial descriptive sensory, compositional, and color properties of juice and juice blends. Ten juice treatments were developed for this study, and the initial composition and color properties are shown in Table 1. Total soluble solids ranged from 10.20% to 15.33% and were higher for 100%Con and Concord juice blends. Titratable acidity (11.66 g/L) and pH (3.31) were highest for 100%Blk juice. Vazquez-Araujo et al. (2010) reported the pH values of blackberry juice, blueberry juice, and assorted pomegranate/blueberry and pomegranate/blackberry juice blends were 3.1 to 3.3, similar to the 100%Blu juice (2.95) and 100%Blk juice (3.31) reported in this study. The 100% Blu juice had the highest total anthocyanins (67.4 mg/100mL). The 100% Blk juice had the highest total phenolics (249 mg/100mL), and 100%Con juice had the highest polymeric color (23.2%).

Initial intensities of the descriptive sensory attributes of the juice blends are presented in Table 2. All significant descriptive attributes including those with low intensities are shown because even low intensity attributes can influence consumer liking. Initial sensory descriptive analysis showed that Concord-containing juices were generally sweeter, less bitter, less astringent, and less sour than blackberry- or blueberry-containing juices. Additionally, Concord and Concord blends had less purple, red, and brown color intensity. As expected, aromatic fruit intensities (blackberry, blueberry, and grape notes) were higher in blends that contained their corresponding fruit.

Correlations were performed to better understand the relationships among compositional, color, and descriptive sensory properties of the juice treatments (Table 3). For the correlations, the descriptive sensory properties included were limited to statistically important attributes. Titratable acidity was negatively correlated to soluble solids (r = -0.94), polymeric color (r = -0.75), sweetness (r = -0.83), and grape note (r = -0.78), which were characteristics strongly associated with Concord juice that had low titratable acidity. Blackberry and blueberry juices had higher titratable acidity, and these fruits were associated with the properties positively correlated with titratable acidity such as total phenolics (r = 0.95), color density (r = 0.74), astringency (r = 0.90), sourness (r = 0.85), bitterness (r = 0.93), and blackberry note (r = 0.90).

Concord juice had higher soluble solids than blueberry or blackberry juice. Soluble solids were positively correlated with properties strongly associated with Concord juice and negatively correlated with properties not strongly associated with Concord juice. Soluble solids were positively correlated with polymeric color (r = 0.87), sweetness (r = 0.92), and grape note (r = 0.90) and negatively correlated with total phenolics (r= -0.96), total anthocyanins (r = -0.79), color density (r = -0.90), red color (r = -0.80), astringency (r = -0.95), sourness (r = -0.89), bitterness (r = -0.98), and blackberry note (r = -0.95).

Total phenolics was positively correlated with astringency (r = 0.88), bitterness (r = 0.95), sourness (r = 0.83), blackberry flavor (r = 0.92), red color (r = 0.75), and color density (r = 0.77). Phenolics in the form of condensed tannins have been shown to have bitter and astringent properties, and some phenolics such as anthocyanins are associated with particular colors. Total phenolics were negatively correlated with polymeric color (r = -0.72), sweetness (r = -0.88), and grape note (r = -0.80) due to lower total phenolic levels in Concord juice.

Anthocyanins are associated with the red-blue colors of certain fruits and vegetables; thus, total anthocyanins correlated with red color (r = 0.59), purple color (r=0.79), and color density (r = 0.97). Polymeric color was inversely correlated with total phenolics (r = -0.72) and total anthocyanins (r = -0.92). Burin et al. (2010) reported relationships between red color and total anthocyanins in grape juice. Total anthocyanins have been shown to have an inverse relationship with polymeric color in other fruit juice products, and the same trend was observed in our study (Hager et al. 2008b, Brownmiller et al. 2008).

Sweetness was inversely correlated to total phenolics (r = -0.88), total anthocyanins (r = -0.75), color density (r = -0.84), and astringency (r = -0.92) and positively correlated with soluble solids (r = 0.92) and polymeric color (r = 0.78). Since Concord juice was reconstituted from concentrate rather than produced from frozen fruit, blends with Concord juice had lower total anthocyanins and higher polymeric color than the other blends. Concord juice tasted sweeter and had higher soluble solids than blueberry or blackberry juice.

Sourness was positively correlated with bitterness (r = 0.90) and blackberry note (r = 0.89) and negatively correlated with grape note (r = -0.89). The descriptive panel found treatments higher in blackberry and blueberry juices more bitter and sour than treatments lower in blackberry and blueberry juices.

Evaluate and identify drivers of consumer acceptance of juice and juice blends. For a product geared toward the competitive marketplace, understanding how these properties influence consumer liking is also important to product success. Overall liking was evaluated by the consumer panel (n = 108) (Table 4). The 100%Con juice (7.79) and the predominant Concord juice blends had high overall liking. The 100%Blu juice (5.47) and predominantly blueberry juice blends had moderate overall liking scores. The 100%Blk juice (2.95) and predominantly blackberry juice blends had low overall liking scores.

Partial least squares regression was used to identify significant positive and negative coefficients toward overall liking. Two factors were used for the descriptive properties model (Figure 2), and four factors were used for the compositional properties model (Figure 3). Cross validation with uncertainty test was utilized to determine p-values for beta coefficients. Grape note and sweetness drove overall liking, which validated the high overall liking for 100%Con and predominantly Concord juice blends (Figure 2). In the compositional PLSR model, soluble solids drove liking, which supports sensory descriptive results (Figure 3). Blackberry note and bitterness were detractors of overall liking, which accounts for the low liking scores for 100%Blk juice. Blueberry juice had lower soluble solids and sweetness than Concord juice, but higher soluble solids and sweetness than blackberry juice, justifying the moderate liking scores for 100%Blu juice. The results in this study were similar to trends reported showing consumers were more accepting of higher percentages of blueberry juice (up to 50%) than blackberry juice (10%) when compared to pomegranate/blueberry and pomegranate/blackberry blends (Vazquez-Araujo et al. 2010).

Color has been shown to be an important component in consumer acceptance of fruit juice (Huggart et al. 1979). Descriptive red and purple color positively affected liking. Total anthocyanins, which contribute the red/blue color to foods, detracted from liking in the compositional PLSR model, which could indicate consumers preferred the hue of Concord juice (lowest in anthocyanins) over the hues of blackberry and blueberry juices. (Color density was not included in the model due to its high correlation with total anthocyanins.) The significance of these color-associated attributes reiterates the importance of product appearance in establishing consumer acceptance. Establishing consumer acceptance is important for a nutraceutical product's longevity because consumers generally only repeat purchase an item if sensory expectations are met.

Assess descriptive and compositional changes of juice and juice blends during storage at 2°C and 21°C. Also crucial for consumer purchases is understanding the compositional changes throughout the product's shelf-life to insure that the product maintains its nutraceutical properties. To promote understanding of potential nutraceutical changes, total phenolics, total anthocyanins, polymeric color, and descriptive sensory attributes were measured during storage at 2°C and 21°C for 200 days. Since minimal descriptive changes occurred during cold temperature storage, ANOVA models were analyzed by temperature. Generally, the juice blends followed the pattern of their primary components.

Total phenolics during storage. For juice stored at 2°C, total phenolics did not change significantly over time, although there were significant differences among blending treatments (Figure 4). Of the single juices, 100%Blk juice was highest in total phenolics followed by 100%Blu and 100%Con juices. Relatively stable total phenolics were also reported for Concord concentrate stored at 5°C for ten months (Boiago Gollucke et al. 2009). Storage at 21°C lowered total phenolics in the juice treatments. At 21°C storage, total phenolics of 100%Con, 100%Blu, and 100%Blk decreased 4.4%, 6.6%, and 5.0% respectively. Juice treatment was significant and followed the same patterns as the samples stored at 2°C. Decreases in total phenolics were also reported for orange juice stored at 18°C, 28°C and 38°C, and losses were greater with increasing temperature (Klimczak et al. 2007). Possibly, compounds besides phenols can react with the Folin-Ciocalteau reagent (Vinson et al. 2001), which may interfere with the accuracy of total phenolics reporting. Total phenolics tend to remain more stable than total anthocyanins because the polymers that are created by the linkage of anthocyanins with procyanidins are also quantified by the total phenolics assay. Total phenolics levels were more consistent for products in cold storage, which suggests that the nutraceutical properties of the juice were better protected at refrigeration temperatures.

Polymeric color during storage. For samples stored at 2°C, polymeric color was significantly higher for 100%Con (28.3%), 100%Blu (7.8%), and 100% Blk (10.4%) at 200 days than at all other time points within each blending treatment. Similar to 100%Con stored at 21°C, 100%Con stored at 2°C at 200 days had the highest polymeric color. The polymeric color values of the remaining 100%Con samples (24.5 to 25.8%) stored at 2°C were significantly higher than all other blending treatments. Samples that contained Concord juice tended to have higher polymeric color, while samples that contained blueberry juice tended to have lower polymeric color. For juice stored at 21°C, polymeric color for 100%Con at 200 days (55.6%) was significantly higher than all other blending treatments at all other time points (Figure 5). The 100%Blu at 0 days had the lowest polymeric color (5.7%), although it was not statistically different than eight other treatments. Polymeric color for 100%Blk ranged from 7.1% (0 days) to 33.0% (200 days). Overall, polymeric color increased for all samples and was highest for 100%Con juice and lowest for 100%Blu juice throughout the study. Changes in polymeric color have consequences for the absorption of phytochemical nutrients. Polymers may interfer with monomeric anthocyanin absorption perhaps due to their molecular structure (Pacheco-Palencia et al. 2010). Refrigeration of juice could delay increases in polymeric color.

Total anthocyanins during storage. Overall, total anthocyanins for juice stored at 2°C decreased significantly from 0 to 68 days and from 102 days to 200 days. After 200 days, percentage decreases of total anthocyanins were 17.8%, 11.2%, and 7.2% for 100%Con, 100%Blu, and 100%Blk respectively. Of the single juices, 100%Blu juice had the highest average total anthocyanins over time (67.0 mg/100mL), followed by 100%Blk juice (51.2 mg/100mL), and 100%Con juice (18.14 mg/100mL). Generally, total anthocyanins decreased as percent polymeric color increased, which has also been observed in other blueberry, blackberry, black raspberry, and grape products (Brownmiller et al. 2008, Burin et al. 2010, Hager et al. 2008a, 2008b, Howard et al. 2010, Kalt et al. 2000). Anthocyanins were polymerized during storage at 2°C and 21°C, with percent polymeric color ranges of 6.1 to 28.3% and 5.7 to 55.6% respectively, although the process was more extreme at 21°C. Likewise, total anthocyanins losses were more extreme at 21°C with ranges of 4.7 mg/100mL to 67.8 mg/100mL compared to 14.9 mg/100mL to 67.0 mg/100mL for samples stored at 2°C. For samples stored at 21°C, total anthocyanins were highest for 100%Blu juice at 0 days (67.8 mg/100mL) and lowest for 100%Con juice at 200 days (4.7 mg/100mL) (Figure 6). Total anthocyanins for juice stored at 21°C decreased for all treatments over time, but at each time point were highest for 100%Blu juice and lowest for 100%Con juice. Total anthocyanins for 100%Blk juice were highest at 0 days (52.1 mg/100mL) and lowest at 200 days (19.3 mg/100mL) and decreased significantly at each time point. After 200 days storage at 21°C, total anthocyanins of 100%Con, 100%Blu, and 100%Blk decreased 73.1%, 45.3%, and 62.9%, respectively.

Since anthocyanins impart the red-blue color to foods, reduction in anthocyanins could indicate a color change. Tannins potentially react with anthocyanins to form brown-colored tannin complexes. Complexes are quantified with the polymeric color assay; thus, decreasing total anthocyanins and increasing polymeric color suggest that the product is becoming browner. Red and purple color as measured by the descriptive panel were significant drivers of liking, which indicates that changes in the product color could detract from consumer acceptance.

Sensory descriptive analysis during storage. Principal component analysis was used to evaluate descriptive sensory data collected at 0 and 200 days. To determine the attributes included in PCA, ANOVA was performed at 200 days. Panelist and blending treatment were considered nominal, and temperature was considered continuous. The first two principal components explain 55.8% percent of the variance (Figure 7). Principal component 1 (38.8%) summarizes differences due to blending treatments, and principal component 2 (17%) quantifies differences due to time. Sensory changes for juice blends stored at differing temperatures were minimal.

Principal component 1 was characterized by the differences among the blending treatments. Generally, Concord-containing juice blends were characterized by sweetness and grape note, blackberry-containing juice blends were characterized by blackberry note, astringency, and bitterness, and blueberry-containing blends were characterized by bitterness and sourness.

Differences due to time were observed for most blending treatments as demonstrated by principal component 2. Smaller differences were observed for 100%Blk, 17%Blu+67%Blk+17%Con, and 50%Blu+50%Blk, potentially because the characteristic bitterness of these blends overwhelmed the perception of any small changes that occurred over time. Sensory stability was shown for Concord juice concentrate stored at 5°C over 8 months (Boiago Golluecke et al. 2008), although in that study fewer attributes (color, astringency, bitterness, sweetness and characteristic grape juice flavor) were examined.

Juice blends stored for 200 days exhibited more brown color and aromatics such as caramelized, fermented, and metallic. According to PLSR (Figure 2), changes in brown color and metallic did not have a significant impact on liking; thus, the impact of changes due to storage on consumer overall liking would be minimal. Fermented and caramelized were not included in the PLSR model because there were not perceived at 0 days. Color degradation occurred over time and was more extreme at higher temperatures for Merlot (*V. Vinefera*) grape juice concentrate (Buglione and Lozano 2002) due in part to non-enzymatic browning.

Changes to juice blends due to storage temperature were smaller for sensory properties than for compositional properties. Results for total phenolics, total anthocyanins, and percent polymeric color indicate that cold storage is crucial for maintaining the nutraceutical quality of the juice blends.

CONCLUSIONS

The properties of the juice blends followed the trends of the primary components, blackberry, blueberry, and Concord juice. Large differences in consumer acceptance and sensory descriptive, compositional, and color properties were found among the fruit juices studied. Consumers found Concord juice more acceptable than blueberry or blackberry juice due in part to its higher soluble solids content. Storage time and temperature were shown to affect total phenolics, total monomeric anthocyanins, polymeric color, and descriptive sensory properties in juice treatments. Blending three fruit juices was shown to enhance nutraceutical properties and maintain consumer acceptability.

REFERENCES

Boiago Golluecke, A.P., J.C. De Souza, and D.D.Q. Tavares. 2008. Sensory stability of Concord and Isabel concentrated grape juices during storage. J. Sens. Stud. 23:340-353.

Boiago Gollucke, A.P., R.R. Catharino, J.C. de Souza, M.N. Eberlin, and D.D.Q. Tavares. 2009. Evolution of major phenolic components and radical scavenging activity of grape juices through concentration process and storage. Food Chem. 112:868-873.

Bravo, L. 1998. Polyphenols: chemistry, dietary sources, metabolism, and nutritional significance. Nutr. Rev. 56:317-333.

Brownmiller, C., L.R. Howard, and R.L. Prior. 2008. Processing and storage effects on monomeric anthocyanins, percent polymeric color, and antioxidant capacity of processed blueberry products. J. Food Sci. 73:H72-H79.

Buglione, M., and J. Lozano. 2002. Nonenzymatic browning and chemical changes during grape juice storage. J. Food Sci. 67:1538-1543.

Burin, V.M., L.D. Falcao, L.V. Gonzaga, R. Fett, J.P. Rosier, and M.T. Bordignon-Luiz. 2010. Colour, phenolic content and antioxidant activity of grape juice. Ciencia Tecnol.Aliment. 30:1027-1032.

Cho, M.J., L.R. Howard, R.L. Prior, and J.R. Clark. 2004. Flavonoid glycosides and antioxidant capacity of various blackberry, blueberry and red grape genotypes determined by high-performance liquid chromatography/mass spectrometry. J. Sci. Food Agric. 84:1771-1782.

Drewnowski, A., and C. Gomez-Carneros. 2000. Bitter taste, phytonutrients, and the consumer: a review. Am. J. Clin. Nutr. 72:1424-1435.

Giusti, M.M., and R.E. Wrolstad. 2004. Unit F1.2: characterization and measurement of anthocyanins by UV-visible spectroscopy. *In* Handbook of food analytical chemistry-pigments, colorants, flavors, texture, and bioactive food components. R.E. Wrolstad (ed.), pp. F1.2.1-F1.2.13. John Wiley & Sons Inc., New York.

Gracia, A., B. Lopez, and S. Virue. 2011. Willingness to pay for natural juice: a choice experiment approach. Itea-Informacion Tecnica Economica Agraria. 107:21-32.

Hager, A., L.R. Howard, R.L. Prior, and C. Brownmiller. 2008a. Processing and storage effects on monomeric anthocyanins, percent polymeric color, and antioxidant capacity of processed black raspberry products. J. Food Sci. 73:H134-H140.

Hager, T.J., L.R. Howard, and R.L. Prior. 2008b. Processing and storage effects on monomeric anthocyanins, percent polymeric color, and antioxidant capacity of processed blackberry products. J. Agric. Food Chem. 56:689-695.

Herrmann, K. 1992. Bitter compounds in fruits and vegetables. Ernahrungs-Umschau. 39:14-19.

Howard, L.R., C. Castrodale, C. Brownmiller, and A. Mauromoustakos. 2010. Jam processing and storage effects on blueberry polyphenolics and antioxidant capacity. J. Agric. Food Chem. 58:4022-4029.

Huggart, R.L., P.J. Fellers, G. De Jager, and J. Brady. 1979. The influence of color on consumer preferences for Florida frozen concentrated grapefruit juices. Proceedings of the Florida State Horticultural Society:148-151.

Igual, M., E. Garcia-Martinez, M.M. Camacho, and N. Martinez-Navarrete. 2011. Changes in flavonoid content of grapefruit juice caused by thermal treatment and storage. Innovative Food Sci. Emerging Tech. 12:153-162.

Iland, P., N. Bruer, G. Edwards, S. Weeks, and E. Wilkes. 2004. Chemical analysis of grapes and wine: techniques and concepts. Patrick Iland Wine Promotions, Australia.

Joseph, J.A., B. Shukitt-Hale, N.A. Denisova, D. Bielinski, A. Martin, J.J. McEwen, and P.C. Bickford. 1999. Reversals of age-related declines in neuronal signal transduction, cognitive, and motor behavioral deficits with blueberry, spinach, or strawberry dietary supplementation. J. Neuroscience. 19:8114-8121.

Kalt, W., J. McDonald, and H. Donner. 2000. Anthocyanins, phenolics, and antioxidant capacity of processed lowbush blueberry products. J. Food Sci. 65:390-393.

Klimczak, I., M. Malecka, M. Szlachta, and A. Gliszczynska-Swiglo. 2007. Effect of storage on the content of polyphenols, vitamin C and the antioxidant activity of orange juices. J. Food Comp. Anal. 20:313-322.

Meullenet, J.-F., R. Xiong, and C.J. Findlay. 2007. Multivariate and probabilistic analyses of sensory science problems. IFT Press and Blackwell Publishing, U.S.A.

Pacheco-Palencia, L.A., S.U. Mertens-Talcott and S.T. Talcott. 2010. In vitro absorption and antiproliferative activities of monomeric and polymeric anthocyanin fractions from açai fruit (Euterpe oleracea Mart.). Food Chem. 119:1071-1078.

Piljac-Zegarac, J., and D. Samec. 2011. Antioxidant stability of small fruits in postharvest storage at room and refrigerator temperatures. Food Res. Int. 44:345-350.

Robichaud, J.L., and A.C. Noble. 1990. Astringency and bitterness of selected phenolics in wine. J.Sci.Food Agric. 53:342-354.

Siegrist, M., N. Stampfli, and H. Kastenholz. 2008. Consumers' willingness to buy functional foods. The influence of carrier, benefit and trust. Appetite. 51:526-529.

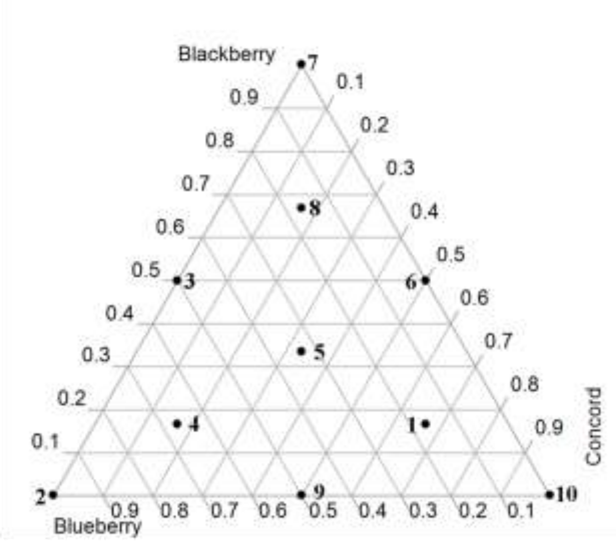
Shukitt-Hale, B., V. Cheng, and J.A. Joseph. 2009. Effects of blackberries on motor and cognitive function in aged rats. Nutr. Neurosci. 12:135-140.

Slinkard, K., and V.L. Singleton. 1977. Total phenol analysis: automation and comparison with manual methods. Am. J. Enol. Vitic. 28:49-55.

Vazquez-Araujo, L., E. Chambers, K. Adhikari, and A.A. Carbonell-Barrachina. 2010. Sensory and physicochemical characterization of juices made with pomegranate and blueberries, blackberries, or raspberries. J. Food Sci. 75:S398-S404.

Vinson, J.A., X.H. Su, L. Zubik, and P. Bose. 2001. Phenol antioxidant quantity and quality in foods: Fruits. J. Agric. Food Chem. 49:5315-5321.

FIG. 1. ABCD MIXTURE DESIGN TERNARY PLOT FOR FORMULATION OF 10 JUICE TREATMENTS



Treatment	Blueberry	Blackberry	Concord
1	17%	17%	67%
2	100%	0	0
3	50%	50%	0
4	67%	17%	17%
5	33%	33%	33%
6	0	50%	50%
7	0	100%	0
8	17%	67%	17%
9	50%	0	50%
10	0	0	100%

TABLE 1. INITIAL COMPOSITION AND COLOR OF JUICE TREATMENTS

Blending treatment	Soluble solids (%)	TA (g/L)[a]	pH	Total phenolics [b]	Polymeric color (%)	Total Acy[c]	Color density
100%Blackberry (Blk)	10.20 h[d]	11.66 a	3.31 a	249.24 a	7.71d ef	51.64 c	17.67 bc
100%Blueberry (Blu)	11.90 e	7.74 g	2.95 f	213.55 de	6.18 f	67.40 a	19.57 a
100%Concord (Con)	15.33 a	4.77 j	3.18 bcd	184.95 f	23.21 a	17.87 h	4.71 h
33%Blu+33%Blk+33%Con	12.30 d	8.01 e	3.15 cd	209.40 de	9.22 cd	47.98 d	12.84 e
17%Blu+17%Blk+67%Con	13.75 b	6.50 h	3.12 de	202.43 e	12.95 b	33.18 g	8.44 g
17%Blu+67%Blk+17%Con	11.23 f	9.81 b	3.26 ab	236.35 ab	8.34 de	49.89 cd	15.61 d
67%Blu+17%Blk+17%Con	12.00 e	7.90 f	3.05 ef	218.14 d	7.43 ef	58.00 b	16.67 cd
50%Blk+50%Con	12.42 d	8.22 d	3.25 abc	218.38 cd	10.66 c	44.87 e	10.89 f
50%Blu+50%Blk	10.90 g	9.67 c	3.14 de	233.76 bc	6.18 f	59.88 b	18.90 ab
50%Blu+50%Con	13.25 c	6.24 i	3.09 de	202.18 e	10.04 c	36.76 f	11.31 f

[a] Titratable acidity (expressed as tartartic acid) analyzed in juice stored at 2°C for 200 days.
[b] Total phenolics expressed as mg gallic equivalents/100 mL juice.
[c] Total anthocyanins expressed as mg/100 mL juice.
[d] Means with different letter(s) for each attribute are significantly different ($p<0.05$) using Tukey's HSD difference method.

TABLE 2. INITIAL INTENSITIES OF DESCRIPTIVE SENSORY ATTRIBUTES OF JUICE TREATMENTS

	Color			Flavor											
Blending treatment	**Brown**	**Purple**	**Red**	**Ast**[a]	**Bitter**	**Sour**	**Sweet**	**Blk note**[a]	**Blu note**[a]	**Grape note**	**Grape skin**	**Burnt**	**Green unripe**	**Metallic**	**Musty dirty**
100%Blackberry (Blk)	1.1 a[b]	10.3 bcd	10.7 ab	7.9 a	2.5 ab	8.3 a	3.5 f	8.6 a	3.4 cd	0.8 cd	0.0a	1.9 a	4.5a	0.5a	0.9abc
100%Blueberry (Blu)	0.2 b	11.4 a	10.1 ab	7.5 bcd	2.0 bc	6.7 abc	4.4 cdef	5.3 bc	6.3 ab	2.4 cd	0.0a	2.1 a	4.1abc	0.0a	0.9abc
100%Concord (Con)	0.3 b	9.6 d	8.3 c	6.9 e	0.9 d	5.3 c	6.7 a	0.0 f	1.6 d	8.8 a	0.5a	2.5 a	3.0d	0.0a	0.8abc
33%Blu+33%Blk+33Con	0.2 b	10.8 ab	10.3 ab	7.6 abc	1.9 c	7.2 abc	4.4 def	4.5 cd	4.7 abc	3.1 cd	0.4a	2.0 a	4.2ab	0.0a	1.3a
17%Blu+17%Blk+67%Con	0.5 ab	10.4 abcd	9.6 b	7.1 de	1.5 c	6.1 bc	5.2 bcd	1.8 ef	3.7 bcd	7.0 ab	0.4a	2.4 a	3.5bcd	0.0a	0.4c
17%Blu+67%Blk+17%Con	0.6 ab	10.8 abc	10.6 ab	7.5 bcd	2.5 ab	7.6 ab	4.1 def	7.3 ab	3.7 bcd	3.3 c	0.0a	2.0 a	4.2ab	0.0a	0.5bc
67%Blu+17%Blk+17%Con	0.2 b	10.9 ab	10.6 ab	7.4 cd	2.0 bc	8.0 ab	4.9 bcde	4.6 cd	6.5 a	3.2 cd	0.0a	1.9 a	4.1abc	0.0a	0.8abc
50%Blk+50%Con	1.0 ab	9.7 cd	11.1 a	7.3 cd	1.8 c	6.4 bc	5.6 abc	2.0 def	4.3 abcd	7.3 ab	0.5a	2.4 a	4.3ab	0.0a	0.9abc
50%Blu+50%Blk	0.9 ab	11.1 ab	10.1 ab	7.8ab	2.6 a	8.5 a	3.8 ef	7.7 ab	3.5 cd	0.6 d	0.0a	1.9 a	4.3ab	0.4a	0.9abc
50%Blu+50%Con	0.2 b	11.3 ab	9.9 b	7. 3cde	1.7 c	7.0 abc	6.0 abc	2.8 cde	4.9 abc	6.2 b	0.4a	2.6 a	3.3cd	0.0a	1.2ab

[a]Astringent (Ast), Blackberry (Blk), Blueberry (Blu)

[b]Means with different letter(s) for each attribute are significantly different ($p<0.05$) using Tukey's HSD.

TABLE 3. CORRELATION MATRIX OF INITIAL COMPOSITIONAL, COLOR AND DESCRIPTIVE PROPERTIES ACROSS BLACKBERRY, BLUEBERRY, AND CONCORD JUICE TREATMENTS

	Soluble solids	TA[a]	Total phenolics	Acy[a]	Polymeric color	Color density	Red color	Purple color	Astr[a]	Sweet	Sour	Bitter	Grape note	Blue note[a]	Blk note[a]
Soluble solids	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TA	-0.94*** [b]	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-
Total phenolics	-0.96***	0.95***	1.00	-	-	-	-	-	-	-	-	-	-	-	-
Acy	-0.79**	0.61	0.61	1.00	-	-	-	-	-	-	-	-	-	-	-
Polymeric color	0.87**	-0.75**	-0.72**	-0.92***	1.00	-	-	-	-	-	-	-	-	-	-
Color density	-0.90***	0.74*	0.77**	0.97***	-0.90***	1.00	-	-	-	-	-	-	-	-	-
Red color	-0.80**	0.75*	0.75*	0.59**	-0.81	0.63	1.00	-	-	-	-	-	-	-	-
Purple color	-0.39	0.28	0.17	0.79**	-0.69*	0.65*	0.21	1.00	-	-	-	-	-	-	-
Astr	-0.95***	0.90***	0.88***	0.75*	-0.79**	0.85**	0.65*	0.38	1.00	-	-	-	-	-	-
Sweet	0.92***	-0.83**	-0.88***	-0.75*	0.78**	-0.84**	-0.61	-0.40	-0.92***	1.00	-	-	-	-	-
Sour	-0.89***	0.85**	0.83**	0.75*	-0.79**	0.82**	0.62	0.50	0.90***	-0.81**	1.00	-	-	-	-
Bitter	-0.98***	0.93***	0.95***	0.77**	-0.85**	0.87**	0.75*	0.43	0.92***	-0.91***	0.90***	1.00	-	-	-
Grape note	0.90***	-0.78**	-0.80**	-0.87**	0.81**	-0.93***	-0.52	-0.57	-0.94***	0.93***	-0.89***	-0.88***	1.00	-	-
Blu note	-0.31	0.13	0.09	0.71	-0.68	0.55	0.51	0.68	0.20	-0.21	0.29	0.23	-0.34	-1.00	-
Blk note	-0.95***	0.90***	0.92***	0.77**	-0.77**	0.88***	0.59	0.45	0.93***	-0.95***	0.89***	0.95***	-0.95***	0.17	1.00

[a] Titratable acidity (TA), Total anthocyanins (Acy), Astringency (Astr), Blueberry (Blu), Blackberry (Blk)

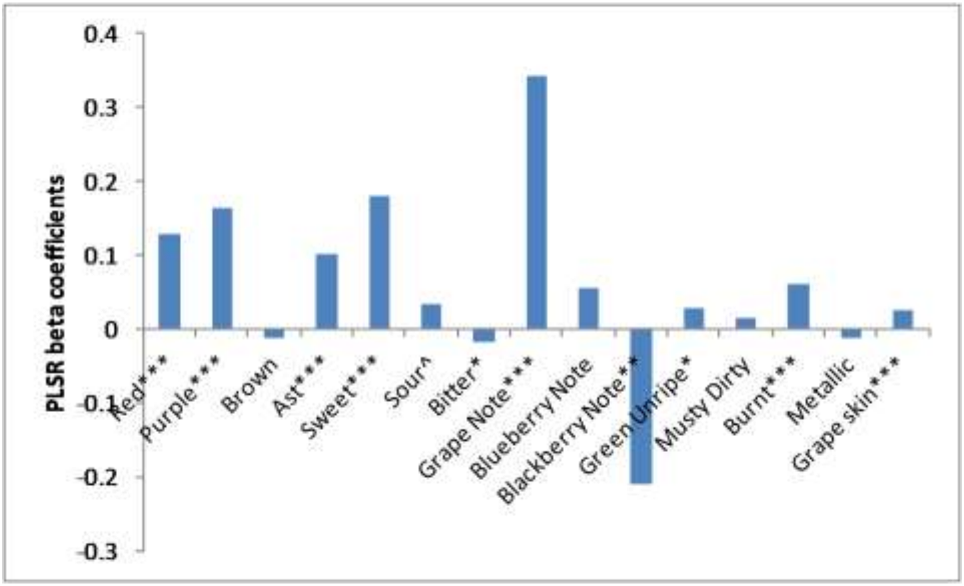
[b] *, **, *** Indicates significance at $p<0.05$, $p<0.01$, $p<0.001$.

TABLE 4. CONSUMER OVERALL LIKING (N=108) OF JUICE TREATMENTS BASED ON THE 9-POINT VERBAL HEDONIC SCALE

Blending treatment	**Overall liking**
100%Blackberry (Blk)	2.95 f [a]
100%Blueberry (Blu)	5.47 d
100%Concord (Con)	7.79 a
33% Blu+33%Blk+33%Con	6.67 bc
17%Blu+17%Blk+67% Con	7.74 a
17%Blu+67% Blk+17% Con	4.35 e
67%Blu+17%Blk+17%Con	6.00 cd
50%Blk+50%Con	6.92 b
50%Blu+50%Blk	4.06 e
50%Blu+50%Con	7.16 ab

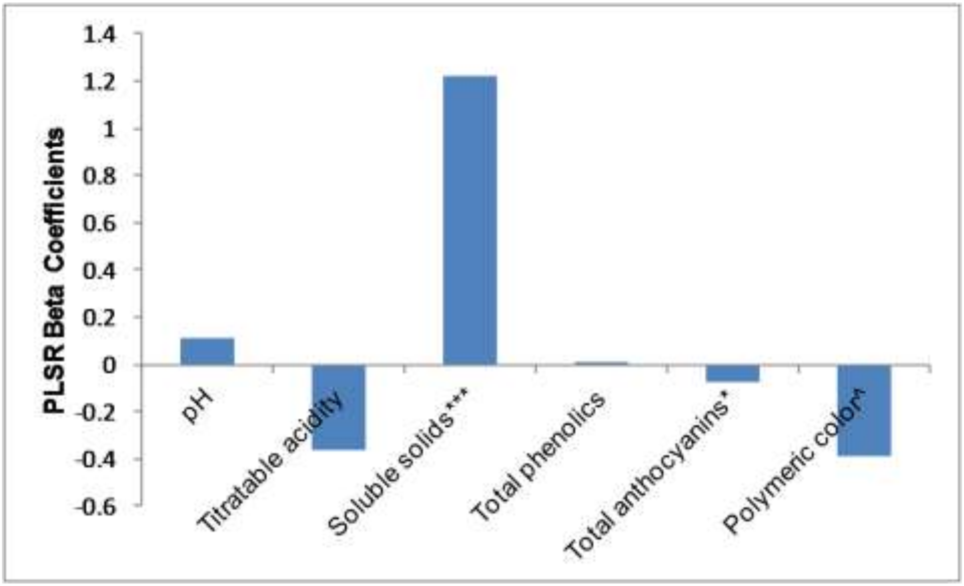
[a]Means with different letter(s) for each attribute are significantly different ($p<0.05$) using Tukey's HSD.

FIG. 2. PARTIAL LEAST SQUARES REGRESSION COEFFICIENTS (PLSR) FOR CONSUMER OVERALL LIKING[a] AS RESPONSE VARIABLE AND SENSORY DESCRIPTIVE ATTRIBUTES AS PREDICTORS FOR BLACKBERRY, BLUEBERRY, AND CONCORD JUICE TREATMENTS[b,c]



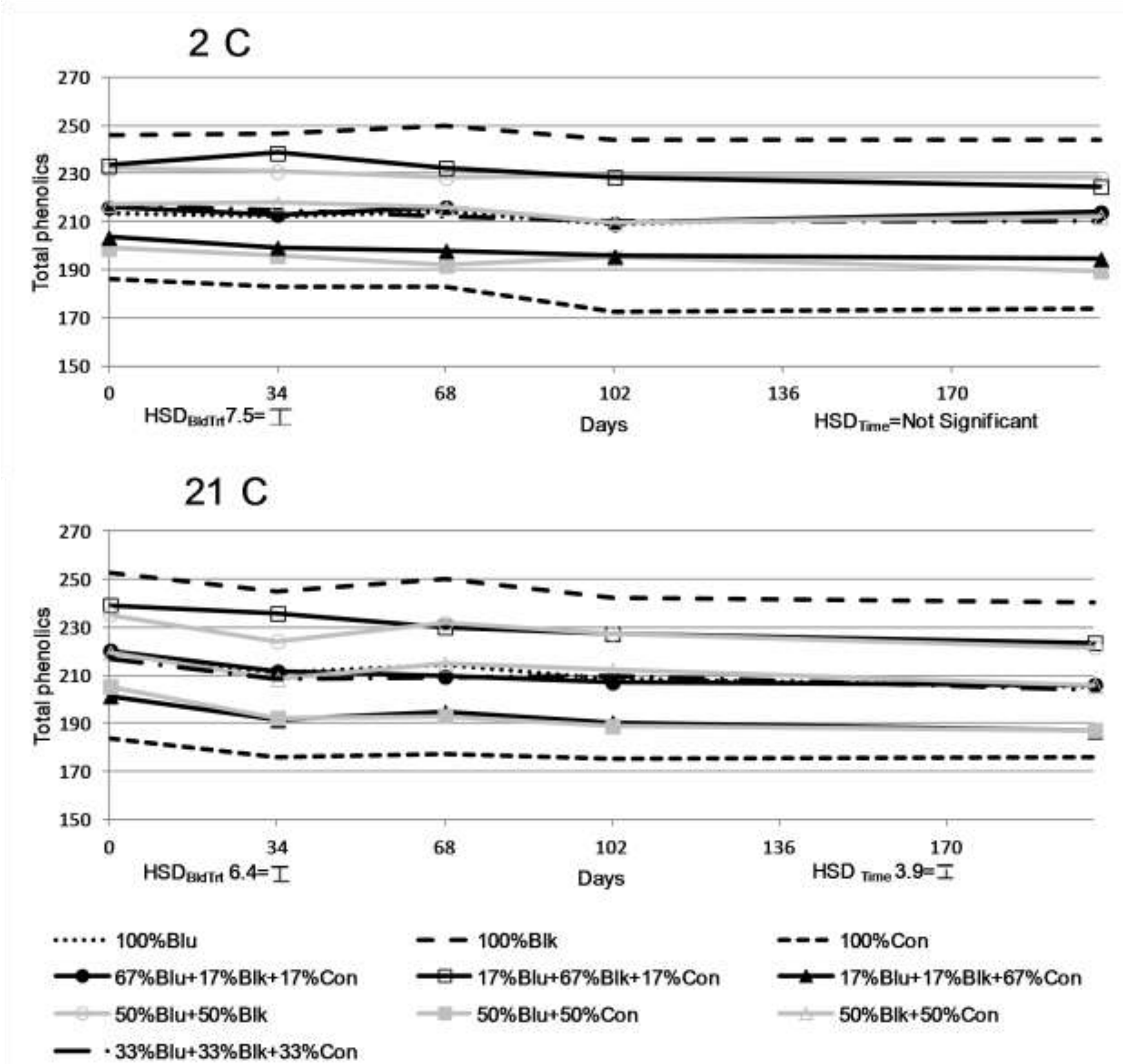
[a] Consumer overall liking measured at 96 days storage at 2°C.
[b] ^,*,**,*** Indicates significance at $p<0.10$, $p<0.05$, $p<0.01$, $p<0.001$, respectively.
[c] Astringency (Ast)

FIG. 3. PARTIAL LEAST SQUARES REGRESSION COEFFICIENTS (PLSR) FOR CONSUMER OVERALL LIKING[a] AS RESPONSE VARIABLE AND COMPOSITIONAL PROPERTIES AS PREDICTORS FOR BLACKBERRY, BLUEBERRY, AND CONCORD JUICE TREATMENTS[b,c]



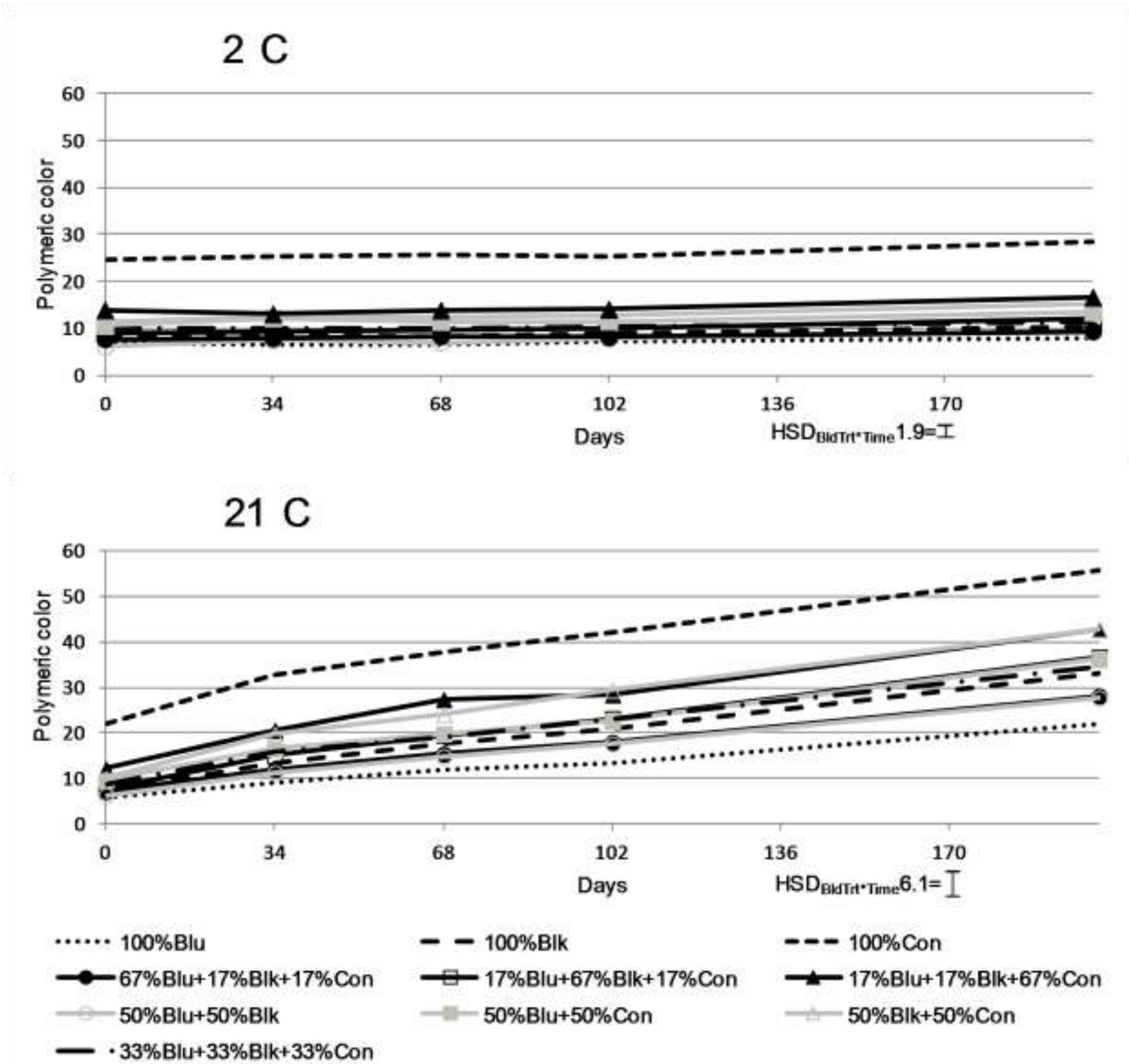
[a] Consumer overall liking measured at 96days storage at 2°C.
[b] ^,*,**,*** Indicates significance at $p<0.10$, $p<0.05$, $p<0.01$, $p<0.001$, respectively.
[c] Percent Polymeric Color (Polymeric Color).

FIG. 4. CHANGES IN TOTAL PHENOLICS (MG/100 ML GALLIC ACID EQUIVALENTS) OF BLACKBERRY (BLK), BLUEBERRY (BLU), AND CONCORD (CON) JUICE AND JUICE BLENDS DURING 200 DAYS STORAGE AT 2°C AND 21°C[a]



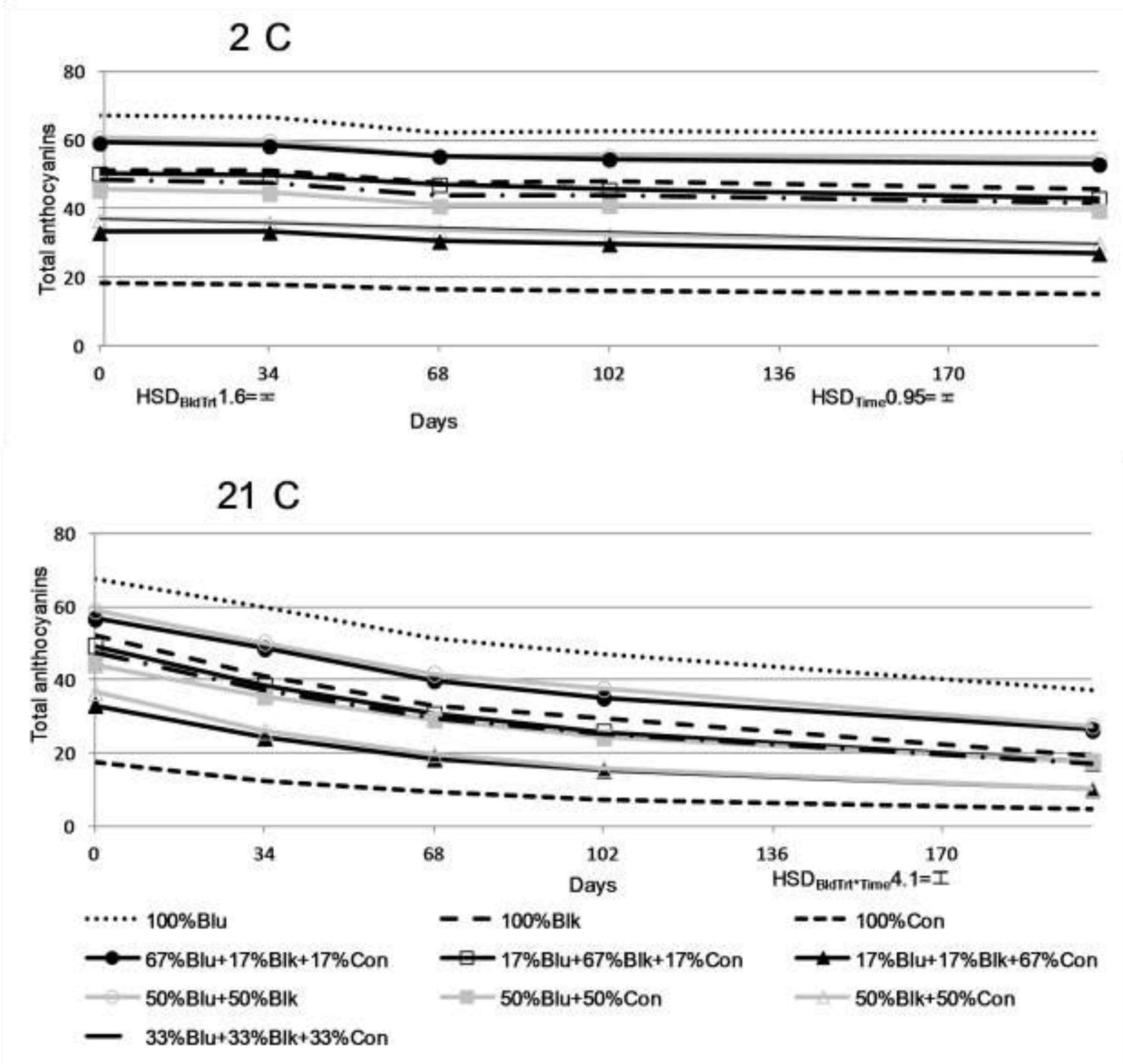
[a]Tukey's HSD bars indicate significant differences at ($p<0.05$).

FIG. 5. CHANGES IN POLYMERIC COLOR (%) OF BLACKBERRY (BLK), BLUEBERRY (BLU), AND CONCORD (CON) JUICE AND JUICE BLENDS DURING 200 DAYS STORAGE AT 2°C AND 21°C[a]



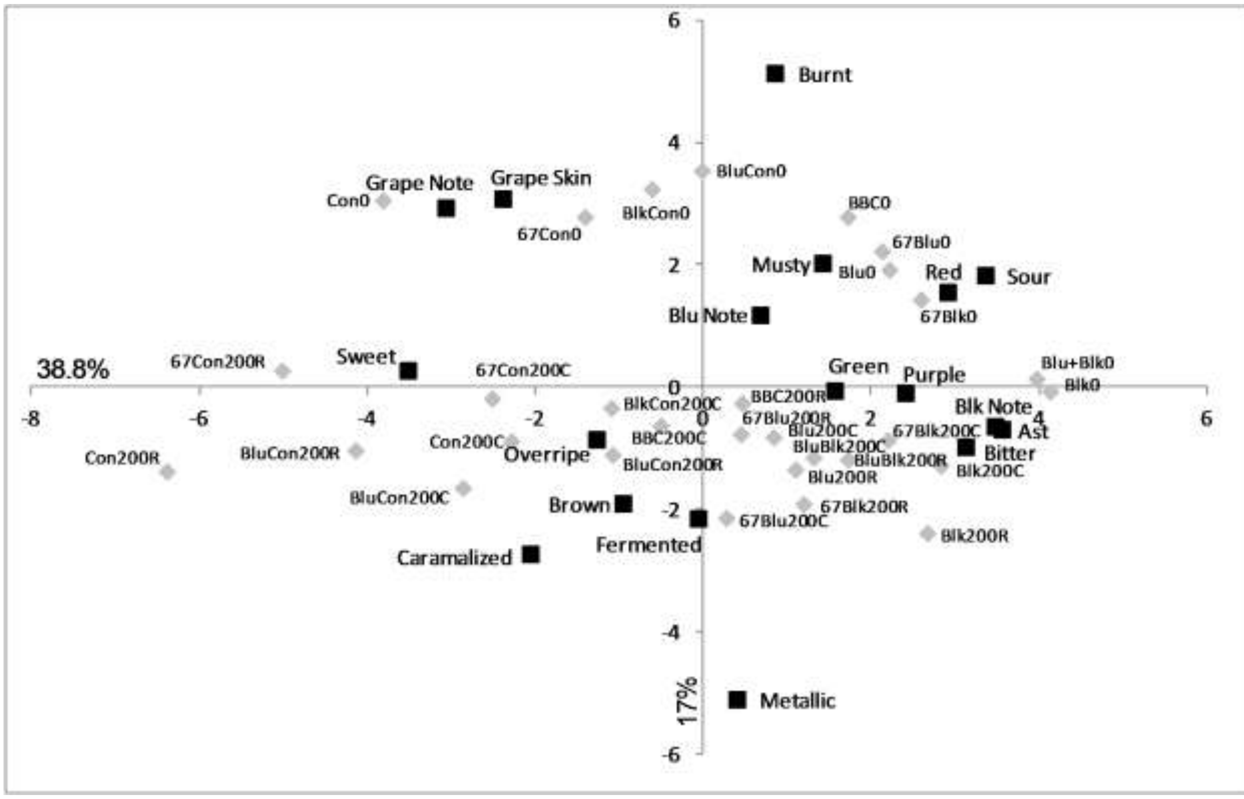
[a]Tukey's HSD bars indicate significant differences at ($p<0.05$).

FIG. 6. CHANGES IN TOTAL MONOMERIC ANTHOCYANINS (MG/100 ML) OF BLACKBERRY (BLK), BLUEBERRY (BLU), AND CONCORD (CON) JUICE AND JUICE BLENDS DURING 200 DAYS STORAGE AT 2°C AND 21°C[a]



[a]Tukey's HSD bars indicate significant differences at ($p<0.05$).

FIG. 7. PRINCIPAL COMPONENT ANALYSIS OF DESCRIPTIVE SENSORY ATTRIBUTES OF BLACKBERRY (BLK), BLUEBERRY (BLU) AND CONCORD (CON) JUICE AND JUICE BLENDS STORED FOR 200 DAYS AT 2°C AND 21°C[a,b]



[a]Abbreviations for treatments: initial time (0); storage for 200 days (200); 21°C storage (R); 2°C storage (C); 100% Concord (Con); 100% blackberry (Blk); 100% blueberry (Blu); 33%blueberry+33%blackberry+33%Concord (BBC); 17%blueberry+17%blackberry+67% Concord (67Con); 17%blueberry+67%blackberry17% Concord (67Blk); 67%blueberry+17%blackberry+17%Concord (67Blu); 50%blackberry+50%Concord (BlkCon); 50%blueberry+50%blackberry(BluBlk); 50%blueberry+50%Concord (BluCon)
[b]Abbreviations for attributes: blackberry note (Blk Note); blueberry note (Blu Note); musty dirty (Musty); green unripe (Green); overripe fruit (Overripe)

CHAPTER 4

Consumer-Based Optimization of Blackberry, Blueberry, and Concord Juice Blends

Lydia J. R. Lawless, Renee T. Threlfall, Luke R. Howard, Jean-François Meullenet

Accepted Contingent upon Revision to the Journal of Sensory Studies

ABSTRACT

The constant fight against aging increases the demand for products that have the potential to promote health. Dark pigmented fruits such as blackberries, blueberries, and Concord grapes show potential to fulfill this demand. Four techniques (response surface, ideal point, desirability function, and intuition) were used to optimize a mixture of blackberry, blueberry, and Concord grape juice based on sensory and potential health properties. Participants (n=108) evaluated ten blending treatments for overall impression on the nine-point verbal hedonic scale and ideal intensities of attributes on the ideal point scale. In a validation study (n=78), the desirability function solution (87% Concord + 13% blackberry) achieved the highest overall liking mean (7.55), although it was not statistically different than the ideal point solution (9% blackberry+20% blueberry+71% Concord) (6.95), the intuitive optimum (66% Concord+34% blueberry) (6.9), or 100% Concord (7.33). When consumers were informed about the anthocyanin content of the juices they were more likely to buy the three juices highest in anthocyanins and less likely to buy the two juice samples lowest in anthocyanins.

PRACTICAL APPLICATIONS

During product development, sensory properties are heavily emphasized as important factors in the final product. However, in light of an aging population, the impact of potential health properties on purchase intent and consumer liking should also be considered. We present approaches that consider the role of both sensory properties and concentration of potentially health beneficial compounds in product optimization.

KEYWORDS

consumer, juice, mixture, multivariate, optimization, product development

INTRODUCTION

As average life expectancy increases, interest in nutraceutical products also increases (Stephens 2008). Juice blends composed of blueberries, blackberries, and Concord grapes may be good candidates for this growing market due to their high polyphenolic content, although some polyphenolic-rich fruits possess astringent and bitter notes that may decrease consumer acceptance (Peleg *et al.* 1999, Vidal *et al.* 2004, Hoye and Ross 2011). Additionally, consumer trends indicate preference for natural juice products (Gracia *et al.* 2011). Thus, optimization strategies that incorporate polyphenolic-containing fruits that are well-liked and avoid the use of additives should be pursued. Blending naturally sweet, polyphenolic-containing fruits such as Concords grapes with other polyphenolic-rich fruits, such as blueberries and blackberries, can aid in maximizing consumer liking while still maintaining high polyphenolic content (Munoz-Espada *et al.* 2004).

Anthocyanins, antioxidants which impart the red-blue color to food, are particular types of polyphenolics found in these fruits. They potentially have chemo-protective effects and the ability to support eye health, brain function, and cardiovascular health (Folts 1998, Seeram *et al.* 2006, Goyarzu *et al.* 2004, Timberlake and Henry 1988). Researchers continue to investigate anthocyanins' potential health benefits, although currently, the Food and Drug Administration (FDA) has not approved anthocyanin health claims (Food and Drug Administration 2011). The purpose of this research is to understand consumer reactions to health claims, which can help direct future research to areas of consumer interest.

In the evolution of product optimization, several statistical optimization techniques have been created (for example, Euclidian Distance Ideal Point Mapping (EDIPM) and extensions to external preference mapping (Tubbs *et al.* 2010, Meullenet *et al.* 2008, Danzart *et al.* 2004)). In this research, statistical methods incorporating concepts from existing multivariate approaches and mixture design experiments were used to formulate the optimum proportions of blackberry, blueberry, and Concord grape juice in a polyphenolic-rich juice blend.

In a mixture experiment, a treatment is represented by the relative proportions of its ingredients, and the ingredients' proportions sum to one. The ternary plot is useful for representing mixture experiments with three components. Any point within the ternary plot represents a three-component blend. From any point within the plot, following the appropriate axis to the side of the plot reveals each component's proportion. The example shows that the mixture represented by Point A is 40% Blackberry, 40% Concord grape, and 20% Blueberry (Figure 1). Mixture designs have previously been used to optimize other beverages such as red wine blends and fruit punch (Kumar *et al.* 2010, Dooley *et al.* 2012).

Differing scaling and optimization strategies were compared to determine the best method. Commonly, product development decisions are determined from consumer liking scores generated using the nine-point verbal hedonic scale (Peryam and Pilgrim 1957). The nine-point hedonic scale is widely used; however, this scale is limited because liking for two products can be reported as equal even when one is closer to the consumer's ideal product. The ideal point scale, however, considers the distance from the consumer's ideal product to the actual product. The ideal point scale can also determine how close actual attribute intensities are to ideal attribute intensities (Worch *et al.* 2010).

PART 1: OPTIMIZATION OF JUICE BLENDS

MATERIALS AND METHODS

Products

Blackberry, blueberry, and Concord juices were produced, bottled and pasteurized at the University of Arkansas Wine Processing Laboratory. Juice was produced from frozen *Natchez* blackberries, *Bluetta* blueberries, and a commercial Concord concentrate according to established procedures (Hager *et al.* 2008). The commercial Concord concentrate was reconstituted to 15% soluble solids. Juice was stored at 42°F (2°C).

Sensory Evaluation

Consumer testing was completed in the University of Arkansas Sensory Service Center. Partitioned white booths accommodated up to thirteen panelists at a time. Computer questionnaires were administered (Compusense *five*, release 4.8, Compusense Inc., Guelph, Ontario, Canada). Panelists (n=108, men=27) were recruited based on their liking of blackberries, blueberries, and Concord grapes and consumption of juice at least three times per week. Consumers were not necessarily required to consume blueberry and blackberry juice on a regular basis because these products are not readily available in the marketplace.

Panelists evaluated two ounces each of the ten blending treatments over a two day period (5 blending treatments/day). The ten blending treatments used in the study were determined by the ABCD mixture design (Table 1) (JMP® 8.0.2, Cary, NC, USA). A balanced complete block design was used to assign the presentation order. Panelists were instructed to rinse their palettes with unsalted crackers and water between samples.

Panelists evaluated the samples for overall liking based on the verbal nine point hedonic scale and ideal intensities of prominent attributes (blackberry, blueberry, and Concord fruit flavor intensity, sweetness, and sourness) based on the ideal point scale.

Compositional Analysis

Total monomeric anthocyanins of the 10 juice blends were measured according to the pH differential method in which samples are treated with potassium chloride (pH=1.0) and sodium acetate (pH=4.5) buffers according to established procedures. Anthocyanin concentration was calculated based on the molecular weight (449.2) and extinction coefficient (26,900) for cyanidin-3-monoglucoside (Cyd3G), with results expressed as mg of Cyd3G equivalents per 100 mL of juice (Giusti and Wrolstad 2004).

Total phenolics were measured according to the Folin-Ciocalteu assay (Slinkard and Singleton 1977) with gallic acid standard. Results were expressed as gallic acid equivalents (GAE/100ml).

Soluble solids were measured with a Bausch & Lomb Abbe Mark II refractometer (Scientific Instrument, Keene, NH).

Statistical Analysis

The data from the ideal point scale and 9-point verbal hedonic scale were analyzed with mixture designs (JMP® version 8.0.2, Cary, NC, USA) by response surface, ideal point, or desirability function optimization techniques. An intuitive optimum was also selected based on bench top optimization. Overall impression, total anthocyanins, and total phenolics were analyzed by ANOVA and Tukey's HSD (α=0.05).

RESULTS AND DISCUSSION

Blending treatments high in Concord juice had the highest overall liking means, followed by predominantly blueberry juice blends and then blackberry juice blends (Table 2). The mean scores for Concord juice blends indicated that Concord juice was well-liked. The scores for predominantly blueberry juice blends were moderate, and the scores for blackberry juice blends were low in the absence of a mitigating blending component.

Possibly, consumers were particularly attracted to Concord because of its natural sweetness and familiar flavor profile. While blueberry juice received lower scores than Concord juice, the flavor profile of blueberry juice was not as polarizing as that of blackberry juice. Blackberry juice was highest in total phenolics, which could have contributed to increased bitterness in the juice (Table 3). Additionally, neophobia could have contributed to decreased acceptance for blueberry and blackberry juice, since these products are not as widely available as Concord grape juice and were therefore less familiar. Similarly, neophobia was shown to be a contributing factor to decreased acceptance of açaí products (Menezes *et al.* 2011).

Blueberry juice was highest in monomeric anthocyanins. The blends followed the trends of their major components. Total phenolics were lower for blackberry juice and higher for blueberry juice than other published values (Vazquez-Araujo *et al.* 2010); however, total phenolics vary widely by cultivar (Howard *et al.* 2003).

Optimization Technique 1: Response Surface

Previously, consumers have been shown to have different approaches to using the verbal nine-point hedonic scale perhaps due to cultural differences, type of food product being tested, or differing preferences for sweetness (Yeh *et al.* 1998, Prescott *et al.* 1997, Bertino *et al.* 1982). Panelists may use the whole nine-point scale or only part of it. The common practice of using product means in data analysis tends to more heavily weight panelists who use only the higher end of the scale; thus, there is value in mapping individual data and allowing all panelists to influence the optimization model equally.

In order to allow all of the indiviudals equal opportunity to influence the optimized product formula, individual overall impression scores elicited from the nine-point hedonic scale were analyzed according to Equation 1 for each panelist. Thus, a response variable is created for each panelist, which creates a series of models with 108 response variables.

Equation 1. Overall Impression (OI)=$\beta_1x_1+\beta_2x_2+\beta_3x_3+\beta_{12}x_1x_2+\beta_{13}x_1x_3+\beta_{23}x_2x_3$,

x_1=blackberry, x_2=blueberry, x_3=Concord

Similar to previous work (Danzart *et al.* 2004), the lower limit for each panelist was set at the individual mean of their responses; thus, the feasible region for each panelist was that which she/he perceived to be above average regardless of how she/he used the scale. Lower limits were indicated by shading. Thus, the lighter areas are those which represented above average liking for most consumers (Figure 2).

The darker areas of the graph indicated combinations of blends to which more consumers were adverse. The solution (18%+Blu+19%Blk+63% Con) was a point at which the majority of consumers were satisfied.

Optimization Technique 2: Ideal point

The consumers were asked how the attribute intensity in a present sample compares to the attribute intensity in their ideal product. The attributes tested included: sweetness, sourness, blackberry flavor intensity, blueberry flavor intensity, and Concord grape flavor intensity. The distance from ideal was calculated (Figure 3).

The mean distance from ideal was taken for each attribute for each of the ten juice samples presented. The set of mean distances for a particular attribute was graphed as its own response. The fruit flavor intensity responses were not included in the final model. Their means suggested that consumers were not familiar enough with blackberry and blueberry juice to determine their ideal intensities for these attributes. For example, the 100% blueberry product had a negative mean for the blackberry flavor attribute, which indicates that consumers wanted less blackberry flavor intensity in that sample. There is no way to achieve this because the level for blackberry is already set at 0. Similarly, the means as a whole were not consistent. In the juice 50%Con+50%Blk, the blackberry flavor mean is positive, which indicates the panelists desired more blackberry flavor intensity. However, in the juice 50%Blu+50%Blk, the blackberry flavor intensity is negative. Both of these samples have the same level of blackberry, although the ideal blackberry flavor intensity is significantly different (Tukey's HSD, α=0.05). Most likely, the perception of blackberry is mitigated and/or influenced by its partner blending component. The likely presence of this confound suggests that the elimination of the fruit intensity variables allows the dataset to be more unbiased. Thus, the sweet and sour ideal distances were the only sensory characteristics included in the final optimization model (Figure 4). Also included was a response for total anthocyanins (polyphenolics with potential health benefits) in the juices.

In this type of ideal point analysis, the objective was to find the point where the present intensity of an attribute met the ideal point of that attribute. In the "ideal" sample, the ideal point would be 0; thus, contours in the mixture profiler were set at 0 with the upper and lower limits set at $\pm$ 0.1. With this shading, there was a narrow feasible region towards the point representing 100% Concord grape juice. The optimum was chosen to be within this area slightly to the left of the sweetness and sourness contours in order to achieve a greater level of anthocyanins, which are highest at the point which represents 100% blueberry juice. While one optimum (9%Blk+20%Blu+71%Con) was chosen, this model had many solutions within the feasible region.

Optimization Technique 3: The Desirability Function

Desirability functions seek to satisfy all response variables equally within the constraints of the model. In this example, each response has a tailored solution for a particular panelist. This solution represents his or her maximized liking score and is assigned a desirability level between 0 and 1, with 1 being the highest level of desirability possible.

In this example, we define overall desirability as the geometric mean of all the responses or $Desirability = \sqrt[108]{y_1 + y_2 + y_3 \ldots + y_{108}}$. The geometric mean demonstrates the central inclination of a set of numbers. We attempted to balance overall liking of all consumers by using the geometric mean.

The most desirable region is located near the point that represents 100% Concord (Figure 5). The most desirable point in the area is 87% Concord and 13% blackberry with a desirability of 0.799427. However, when rounded to three significant digits, there are many points near the solution that are almost equally desirable. The points that have a desirability of 0.799 are shown (Table 4). From this region, desirability decreases linearly across the map surface.

Optimization Technique 4: Intuition

Often in the product development, researchers rely on intuition to create products that are liked by the consumer. The same rationale was applied to our juice blend. While Concord grape juice was an important component for its natural sweetness, blueberry juice contributed high anthocyanin content and good color without as much bitterness as blackberry. Thus, a blend was created with the highest possible percentage of blueberry while maintaining an appropriate sweetness level. The final intuitive solution was 66% Concord and 34% blueberry.

All four of the calculated optima contained predominantly Concord juice, most likely due to the familiarity and sweetness of Concord grapes. The sugar to acid ratio of juices can be standardized to balance flavor components, but this approach was not pursued to satisfy consumer desire for more natural juices (Walker *et al.* 2001, Flora 1979).

PART 2: VALIDATION OF JUICE BLEND OPTIMIZATIONS

MATERIALS AND METHODS

Experimental Design

In the ternary plot, the four generated optima fall near the point that represents 100% Concord juice. Three blends from the original ABCD design naturally framed the optima and were used to foster meaningful comparisons among the optimized solutions. The resulting design for the validation study is represented (Figure 6).

Samples

The juice used to create optimized blends for the validation study was the same juice used in Part 1.

Procedure

Consumers from the intial study were invited to return for the validation study. Panelists (n=78, men=17, women=61) tasted two ounce servings each of seven juice treatments during one testing day. Consumers were asked to evaluate their overall impression based on the verbal nine-point hedonic scale and their ideal attribute intensities based on the ideal point scale. After tasting each product, consumers were questioned about their purchase intent based on the sensory properties of the juice alone. Then, consumers were given additional information about the potential health benefits of anthocyanins, a prominent polyphenolic in the juice blend, and asked to reevaluate their purchase intent. The information provided included the estimated level of anthocyanins for that sample, the ranking of that anthocyanin among all seven samples, and specific areas of potential action for anthocyanins (e.g. promotion of eyesight, neurological protective effect, and prevention of clogged arteries (Folts 1998,Timberlake and Henry 1988, Joseph *et al.* 1999, Joseph *et al.* 1998)).

Statistical Analysis

ANOVA and mean separation were performed (JMP® 8.0.2, Cary, NC, USA). Matched pair analysis was performed on purchase intent data to determine if significant shifts in purchase intent occurred after the information treatment (JMP® 8.0.2, Cary, NC, USA).

RESULTS AND DISCUSSION

Overall Impression

The desirability function solution received the highest overall impression mean, although it was not significantly higher than the intuitive optimum, 100%Con juice, or the ideal solution (Table 5). In the original study, 100%Con, 17%+Blu+17%Blk+67% Con, and 50%Blu+50%Con juices received the highest overall impression means, although in the validation study, juice from three out of four the optimized solutions were liked significantly more than 50%Blu+50%Con. The juice blend optimized by response surface was not liked as much as 100%Con juice in the validation study. Interestingly, it had a similar formula (18%+Blu+19%Blk+63% Con) to 17%+Blu+17%Blk+67% Con in the initial study, which was liked as much as 100%Con in the initial study. The increased separation among products could be due to the wider range of larger and more polarizing differences among products in the initial study.

Blends that were liked more than 100%Con juice were not created by the optimization methods; however, three of the optimized blends were liked just as well, and they contained more anthocyanins and/or phenolics than 100%Con juice. The original objective, which was to optimize products based on sensory and nutraceutical properties, was achieved.

Purchase Intent

For the three juices highest in anthocyanins, purchase intent significantly increased when panelists were informed of these samples' anthocyanin ranks (in terms of concentration) and of the potential health benefits of anthocyanins (Table 6). For the two juices lowest in anthocyanins, purchase intent decreased. The shifts in the distribution of purchase intent are especially substantial for the products with the highest (50%Blu+50%Con) (Figure 7) or lowest anthocyanin content (100%Con) (Figure 8). These results indicated that familiarizing consumers with the benefits of anthocyanins and the relative amounts of anthocyanins in juices may significantly impact purchase decisions. The shifts in purchase intent after consumers were given anthocyanin information could have been due to the content of the claim. Uraguayan consumers identified cardiovascular diseases as a preferred area of action for functional foods (i.e., nutraceuticals) (Ares *et al.* 2008). Similar trends may exist for American consumers as well as prevention of clogged arteries was addressed in the anthocyanin health statement.

Prior studies have also shown that consumers were more willing to buy products that were associated with physiological characteristics, such as disease prevention rather than psychological characteristics (Siegrist *et al.* 2008). The benefits presented to consumers in this study were physiological, which could also explain the positive response to the health information. The results here follow similar trends that were found for food bars for which health-related claims such as "contains whole grains/oats" contributed to purchase intent (Mahanna *et al.* 2009).

Communicating health benefits to the consumer can have a significant impact on their purchase intent even for products that are not the most well-liked in terms of sensory properties. This serves as a directive to future researchers. In terms of purchase intent, consumers are more likely to purchase juice products with health claims pertinent to anthocyanins. Thus, efforts to validate the health benefits of these compounds may be worthwhile endeavors.

These results invoke discussion about consumers' tradeoffs between taste and health. Differing population segments were shown to have differing expectations for an antioxidant-enriched chocolate dessert (Ares *et al.* 2010). For some consumers, the unexpected herb flavor in the antioxidant-enriched product interfered with product acceptance, while other consumers who expected the off-flavor had higher actual liking than expected liking (Ares *et al.* 2010). The decrease in consumer liking due to off-flavors can be partially offset with health benefit claims (Tuorila and Cardello 2002). Furthermore, off-flavors in functional products may be less important to particular population segments which may attribute high importance to the health aspects of the product (Ares *et al.* 2010). The potential trade-off between health and sensory properties reinforces the need for optimization techniques which can accommodate health and sensory characteristics.

Consumers were more willing to buy nutraceutical products when the base product was perceived as healthy (Siegrist *et al.* 2008, Annunziata and Vecchio 2011). Dark fruit juice may be perceived as healthy because dark fruits such as cranberry juice may help prevent urinary tract infections (Stothers 2002). Consumers may project this healthy connotation onto similar products, although additional research is needed to confirm this. Furthermore, fruit juice provides consumers a convenient way to consume their daily dietary requirements of fruit (Gracia *et al.* 2011). Sensory appeal, price, and convenience were identified as the top three most important considerations in food choice (Carrillo *et al.* 2011). More natural functional benefit and carrier product combinations may be more desirable in terms of purchase intent if the consumer is not already familiar with the carrier-ingredient combination (Krutulyte *et al.* 2011). The optimized juice blends in this study had the added advantage of anthocyanins occurring naturally in blueberries, blackberries, and Concord grapes.

Three out of the four optimization methods utilized (desirability function, ideal point, and intuition) were liked as well as 100%Con juice, the winner from Part 1 of this study. The optimized solutions had the added benefit of higher anthocyanin and phenolic contents. Future research could test these optimization methods in a wider array of products.

When given comparative nutraceutical information, the majority of consumers were more likely to purchase the products higher in anthocyanins. This suggests that pursuing research that validates the health benefits of anthocyanins and informing consumers of these benefits could have positive results in the marketplace.

REFERENCES

ANNUNZIATA, A. and VECCHIO, R. 2011. Functional foods development in the European market: A consumer perspective. Journal of Functional Foods *3*, 223-228, DOI: 10.1016/j.jff.2011.03.011.

ARES, G., BARREIRO, C., DELIZA, R., GIMENEZ, A. and GAMBARO, A. 2010. Consumer expectations and perception of chocolate milk desserts enriched with antioxidants. J. Sens. Stud. *25*, 243-260. DOI: 10.1111/j.1745-459X.2010.00293.x.

ARES, G., GIMENEZ, A. and GAMBARO, A. 2008. Uruguayan consumers' perception of functional foods. J. Sens. Stud. *23,* 614-630.

BERTINO, M., BEAUCHAMP, G.K. and ENGLEMON, K. 1982. Rated taste perception in two cultural groups. Chemical Senses *8*, 3-15.

CARRILLO, E., VARELA, P., SALVADOR, A. and FISZMAN, S. 2011. Main factors underlying consumers' food choice: A first step for the understanding of attitudes toward "healthy eating". J. Sens. Stud. *26*, 85-95, DOI: 10.1111/j.1745-459X.2010.00325.x.

DANZART, M., SIEFFERMANN, J.M. and DELARUE, J. 2004. New developments in preference mapping techniques: finding out a consumer optimal product, its sensory profile and the key sensory attributes. Seventh Sensometrics Meeting.

DOOLEY, L., THRELFALL, R.T. and MEULLENET, J.F. 2012. Optimization of blended wine quality through maximization of consumer liking. Food Qual. Prefer. *24*, 40-47.

FLORA, L.F. 1979. Optimum quality parameters of muscadine grape juices, beverages, and blends. Journal of Food Quality *2*, 219-229.

FOLTS, J.D. 1998. Antithrombotic potential of grape juice and red wine for preventing heart attacks. Pharm. Biol. *36*, 21-27.

FOOD AND DRUG ADMINISTRATION 2011. Qualified Health Claims. http://www.fda.gov/Food/LabelingNutrition/LabelClaims/QualifiedHealthClaims/default.html (accessed July 20, 2011).

GIUSTI, M.M. and WROLSTAD, R.E. 2004. Unit F1.2: characterization and measurement of anthocyanins by UV-visible spectroscopy. In *Handbook of food analytical chemistry-pigments, colorants, flavors, texture, and bioactive food components*, (R.E. Wrolstad, ed.) pp. F1.2.1-F1.2.13, John Wiley & Sons Inc., New York.

GOYARZU, F., MALIN, D.H., LAU, F.C., TAGLIALATELA, G., MOON, W.D., JENNINGS, R., MOY, E., MOY, D., LIPPOLD, S., SHUKITT-HALE, B. and JOSEPH, J.A. 2004. Blueberry supplemented diet: Effects on object recognition memory and nuclear factor-kappa B levels in aged rats. Nutr. Neurosci. *7*, 75-83, DOI: 10.1080/10284150410001710410.

GRACIA, A., LOPEZ, B. and VIRUE, S. 2011. Willingness to pay for natural juice: a choice experiment approach. Itea-Informacion Tecnica Economica Agraria *107*, 21-32.

HAGER, T.J., HOWARD, L.R. and PRIOR, R.L. 2008. Processing and storage effects on monomeric anthocyanins, percent polymeric color, and antioxidant capacity of processed blackberry products. J. Agric. Food Chem. *56*, 689-695, DOI: 10.1021/jf071994g.

HOWARD, L.R., CLARK, J.R. and BROWNMILLER, C. 2003. Antioxidant capacity and phenolic content in blueberries as affected by genotype and growing season. J. Sci. Food Agric. *83*, 1238-1247, DOI: 10.1002/jsfa.1532.

HOYE, C., JR. and ROSS, C.F. 2011. Total Phenolic Content, Consumer Acceptance, and Instrumental Analysis of Bread Made with Grape Seed Flour. J. Food Sci. *76*, S428-S436, DOI: 10.1111/j.1750-3841.2011.02324.x.

JOSEPH, J.A., SHUKITT-HALE, B., DENISOVA, N.A., BIELINSKI, D., MARTIN, A., MCEWEN, J.J. and BICKFORD, P.C. 1999. Reversals of age-related declines in neuronal signal transduction, cognitive, and motor behavioral deficits with blueberry, spinach, or strawberry dietary supplementation. Journal of Neuroscience *19*, 8114-8121.

JOSEPH, J.A., SHUKITT-HALE, B., DENISOVA, N.A., PRIOR, R.L., CAO, G., MARTIN, A., TAGLIALATELA, G. and BICKFORD, P.C. 1998. Long-term dietary strawberry, spinach, or vitamin E supplementation retards the onset of age-related neuronal signal-transduction and cognitive behavioral deficits. Journal of Neuroscience *18*, 8047-8055.

KRUTULYTE, R., GRUNERT, K.G., SCHOLDERER, J., LAHTEENMAKI, L., HAGEMANN, K.S., ELGAARD, P., NIELSEN, B. and GRAVERHOLT, J.P. 2011. Perceived fit of different combinations of carriers and functional ingredients and its effect on purchase intention. Food Qual. Prefer. *22*, 11-16, DOI: 10.1016/j.foodqual.2010.06.001.

KUMAR, S.B., RAVI, R. and SARASWATHI, G. 2010. Optimization of fruit punch using mixture design. J. Food Sci. *75*, S1-S7, DOI: 10.1111/j.1750-3841.2009.01379.x.

MAHANNA, K., MOSKOWITZ, H.R. and LEE, S.-. 2009. Assessing consumer expectations for food bars by conjoint analysis. J. Sens. Stud. *24*, 851-870, DOI: 10.1111/j.1745-459X.2009.00241.x.

MENEZES, E., DELIZA, R., CHAN, H.L. and GUINARD, J. 2011. Preferences and attitudes towards acai-based products among North American consumers. Food Res. Int. *44*, 1997-2008, DOI: 10.1016/j.goodres.2011.02.048.

MEULLENET, J.-., LOVELY, C., THRELFALL, R., MORRIS, J.R. and STRIEGLER, R.K. 2008. An ideal point density plot method for determining an optimal sensory profile for Muscadine grape juice. Food Quality and Preference *19*, 210-219, DOI: 10.1016/j.foodqual.2007.06.011.

MUNOZ-ESPADA, A.C., WOOD, K.V., BORDELON, B. and WATKINS, B.A. 2004. Anthocyanin quantification and radical scavenging capacity of Concord, Norton, and Marechal Foch grapes and wines. J. Agric. Food Chem. *52*, 6779-6786, DOI: 10.1021/jf040087y.

PERYAM, D.R. and PILGRIM, F.J. 1957. The Hedonic Scale Method of Measuring Food Preference. Food Technol. *11*, 32-32.

PELEG, H., GACON, K., SCHLICH, P. and NOBLE, A.C. 1999. Bitterness and astringency of flavan-3-ol monomers, dimers and trimers. J. Sci. Food Agric. *79*, 1123-1128.

PRESCOTT, J., KORAC, S., ALLEN, S., YAMAZAKI, K., O'SULLIVAN, M., BELL, G.A., GILMORE, R. and YOSHIDA, M. 1997. Cross-cultural comparisons of Japanese and Australian responses to manipulations of sweetness in food. Food Qual. Prefer. *8*, 45-55.

SEERAM, N.P., ADAMS, L.S., ZHANG, Y., LEE, R., SAND, D., SCHEULLER, H.S. and HEBER, D. 2006. Blackberry, black raspberry, blueberry, cranberry, red raspberry, and strawberry extracts inhibit growth and stimulate apoptosis of human cancer cells in vitro. J. Agric. Food Chem. *54*, 9329-9339, DOI: 10.1021/jf061750g.

SIEGRIST, M., STAMPFLI, N. and KASTENHOLZ, H. 2008. Consumers' willingness to buy functional foods. The influence of carrier, benefit and trust. Appetite *51*, 526-529, DOI: 10.1016/j.appet.2008.04.003.

SLINKARD, K. and SINGLETON, V.L. 1977. Total phenol analysis - automation and comparison with manual methods. Am. J. Enol. Vitic. *28*, 49-55.

STEPHENS, G. 2008. Baby boomers and the role of nutraceutical ingredients. Cereal Foods World *53*, 306-307, DOI: 10.1094/CFW-53-60.

STOTHERS, L. 2002. A randomized trial to evaluate effectiveness and cost effectiveness of naturopathic cranberry products as prophylaxis against urinary tract infection in women. Can. J. Urol. *9*, 1558-1562.

TIMBERLAKE, C.F. and HENRY, B.S. 1988. Anthocyanins as natural food colorants. Progress in clinical and biological research *280*, 107-121.

TUBBS, J., OUPADISSAKOON, G., LEE, Y.S. and MEULLENET, J. 2010. Performance and representation of Euclidian Distance Ideal Point Mapping (EDIPM) using a third dimension. Food Quality and Preference *21*, 278-285, DOI: 10.1016/j.foodqual.2009.08.008.

TUORILA, H. and CARDELLO, A.V. 2002. Consumer responses to an off-flavor in juice in the presence of specific health claims. Food Qual. Prefer. *13*, 561-569.

VAZQUEZ-ARAUJO, L., CHAMBERS, E., ADHIKARI, K. and CARBONELL-BARRACHINA, A.A. 2010. Sensory and physicochemical characterization of juices made with pomegranate and blueberries, blackberries, or raspberries. J. Food Sci. *75*, S398-S404, DOI: 10.1111/j.1750-3841.2010.01779.x.

VIDAL, S., FRANCIS, L., NOBLE, A., KWIATKOWSKI, M., CHEYNIER, V. and WATERS, E. 2004. Taste and mouth-feel properties of different types of tannin-like polyphenolic compounds and anthocyanins in wine. Anal. Chim. Acta *513*, 57-65, DOI: 10.1016/j.aca.2003.10.017.

WALKER, T., MORRIS, J., THRELFALL, R., MAIN, G., LAMIKANRA, O. and LEONG, S. 2001. Density separation, storage, shelf life, and sensory evaluation of 'Fry' muscadine grapes. HortScience *36*, 941-945.

WORCH, T., SÉBASTIEN, L., PUNTER, P. and JÉRÔME, P. 2010. Can we trust consumers' ideal? Study of the relationship between the consumers' preference and their ideals.

YEH, L.L., KIM, K.O., CHOMPREEDA, P., RIMKEEREE, H., YAU, N.J.N. and LUNDAHUL, D.S. 1998. Comparison in use of the 9-point hedonic scale between Americans, Chinese, Koreans, and Thai**.** Food Qual. Prefer. *9*, 413-419.

FIG. 1. UNDERSTANDING THE TERNARY PLOT FOR THREE-COMPONENT MIXTURE DESIGNS

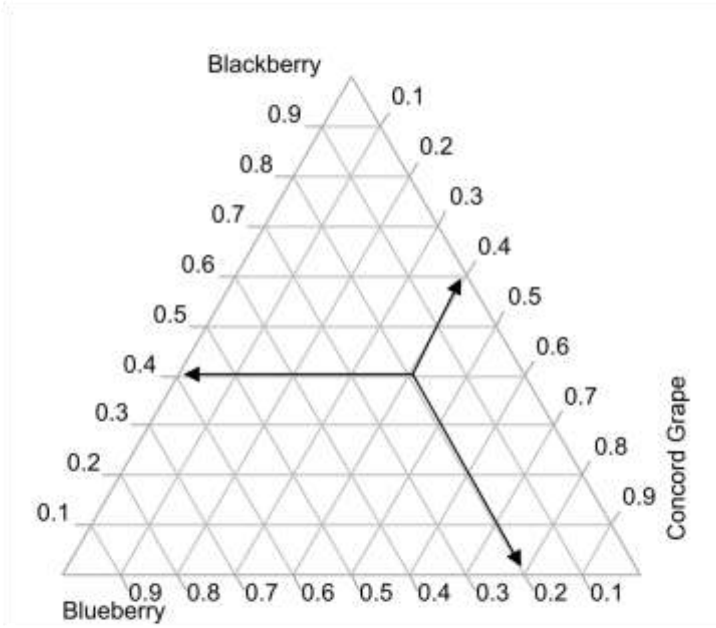


TABLE 1. ABCD MIXTURE DESIGN BLENDING TREATMENTS

Blueberry	Blackberry	Concord
17%	17%	67%
100%	0	0
50%	50%	0
67%	17%	17%
33%	33%	33%
0	50%	50%
0	100%	0
17%	67%	17%
50%	0	50%
0	0	100%

TABLE 2. INITIAL CONSUMER STUDY JUICE OVERALL IMPRESSION MEANS[a,b]

Product	Overall Impression Mean
100%Con	7.79a
17%Blu+17%Blk+67% Con	7.74a
50%Blu+50%Con	7.16ab
50%Blk+50%Con	6.92b
33%Blu+33%Blk+33%Con	6.67bc
67%Blu+17%Blk+17%Con	6.00cd
100%Blu	5.47d
17%Blu+67% Blk+17% Con	4.35e
50%Blu+50%Blk	4.06e
100%Blk	2.95f

[a]Means with different letter(s) for each attribute are significantly different ($p<0.05$) using Tukey's HSD difference method.
[b]Abbreviations: Blueberry (Blu), Blackberry (Blk), Concord grape (Con)

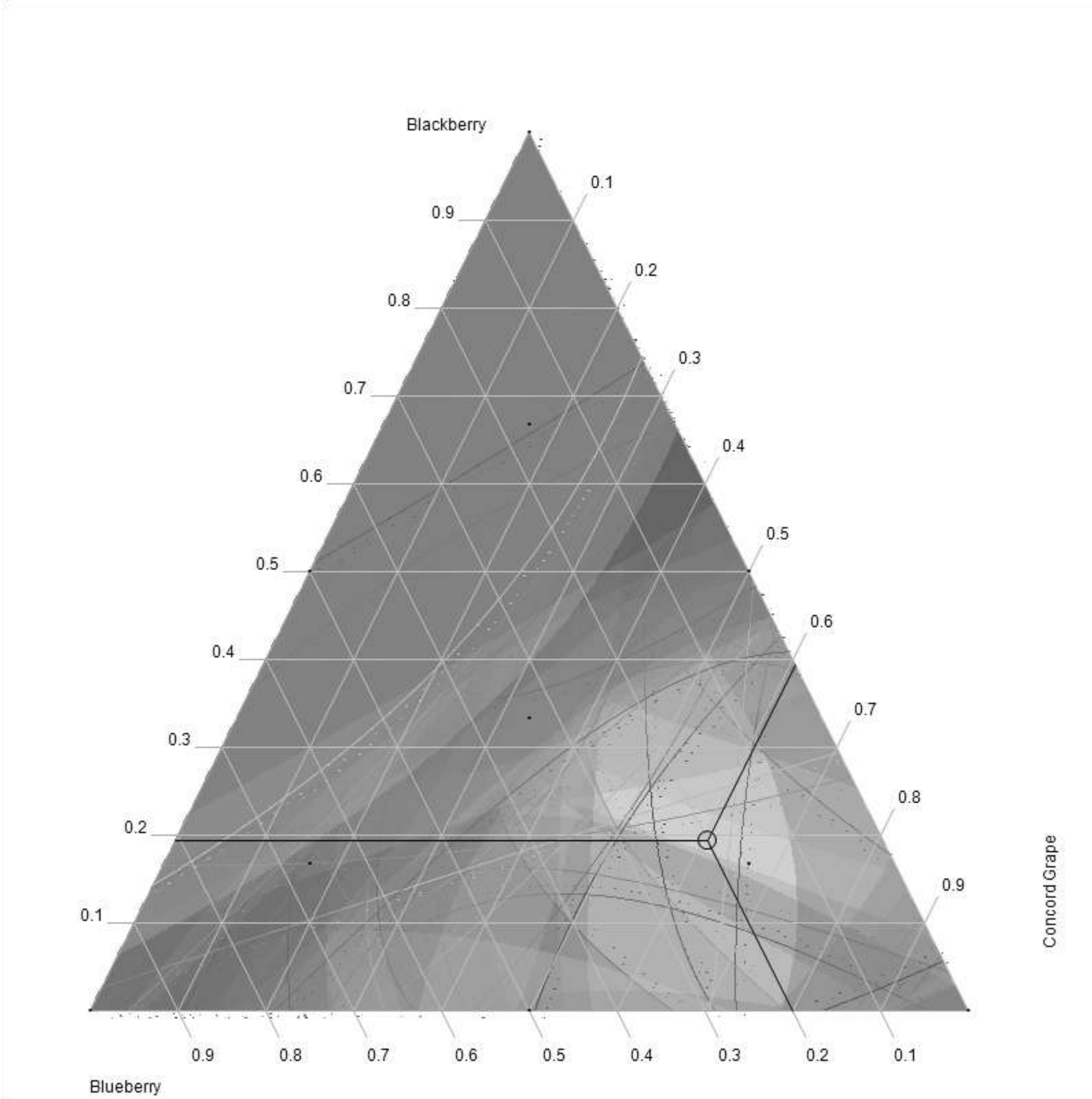
TABLE 3. JUICE NUTRACEUTICAL PROPERTY MEANS[a,b]

Blending Treatment	Total Anthocyanins (mg/100 ml)	Total Phenolics (GAE/100 ml)	Soluble Solids (%)
100%Blu	62.76a	208.78cd	11.90e
50%Blu+50%Blk	55.50b	228.70b	10.90g
67%Blu+17%Blk+17%Con	54.57b	209.26cd	12.00e
100%Blk	48.03c	243.72a	10.20h
17%Blu+67%Blk+17%Con	45.72d	228.62b	11.23f
33%Blu+33%Blk+33%Con	43.77e	209.95c	12.30d
50%Blu+50%Con	41.12f	195.04d	13.25c
50%Blk+50%Con	32.53g	209.72c	12.42d
17%Blu+17%Blk+67%Con	29.86h	195.72cd	13.75b
100%Con	15.88i	172.30e	15.33a

[a]Means with different letter(s) for each attribute are significantly different ($p<0.05$) using Tukey's HSD difference method.

[b]Abbreviations: Blueberry (Blu), Blackberry (Blk), Concord grape (Con)

FIG. 2. RESPONSE SURFACE WITH CONSUMER HEDONIC MEANS[a]

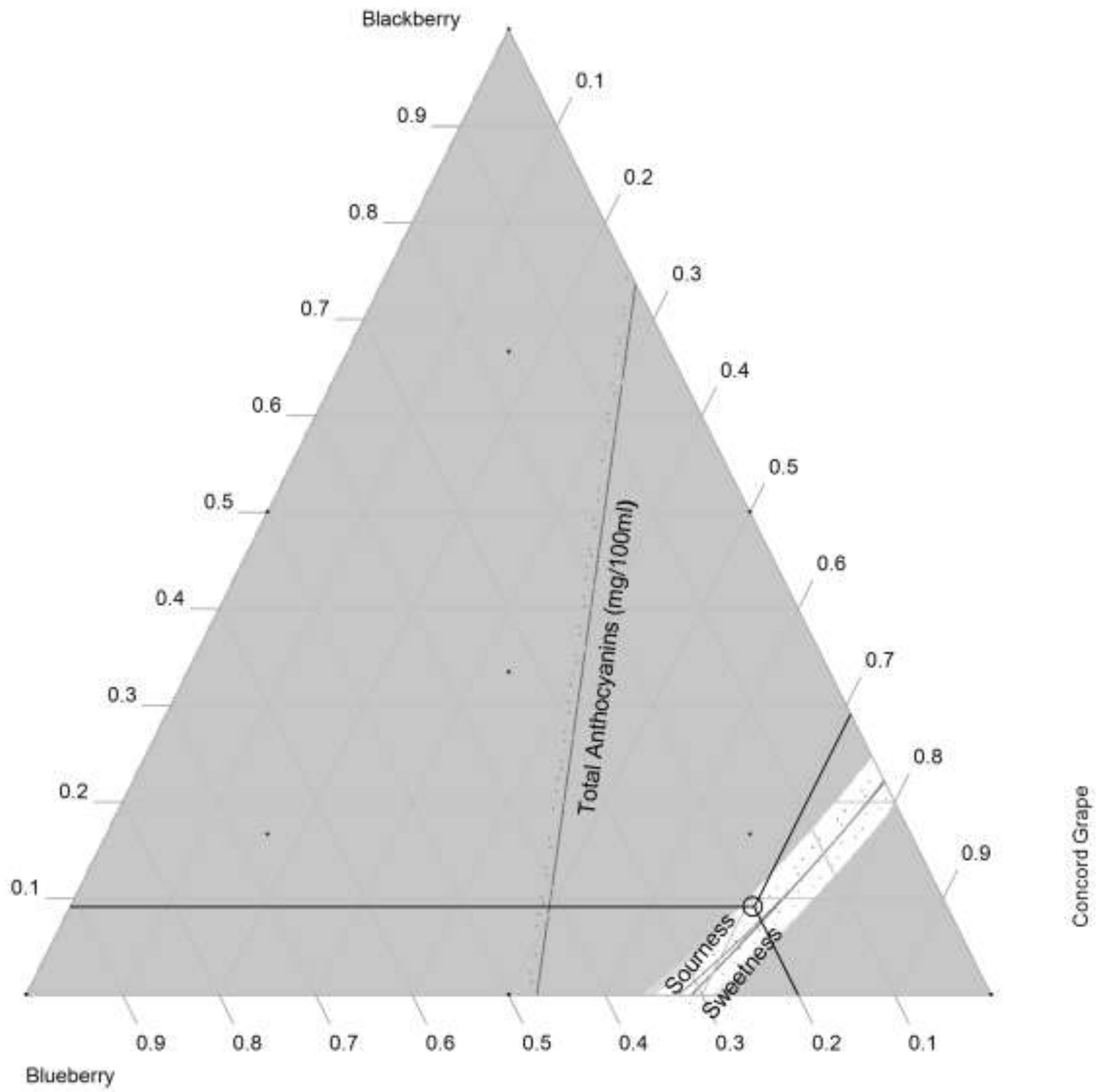


[a]Shading light to dark indicates above average liking for more consumers to above average liking for fewer consumers

FIG. 3. IDEAL POINT FORMULA

Distance from left anchor for ideal sample	-	Distance from left anchor for present sample	=	Ideal point for present sample

FIG. 4. IDEAL POINT[a]



[a]Sweetness and sourness calculated from mean distance from ideal for 108 consumers

FIG. 5. DESIRABILITY FUNCTION

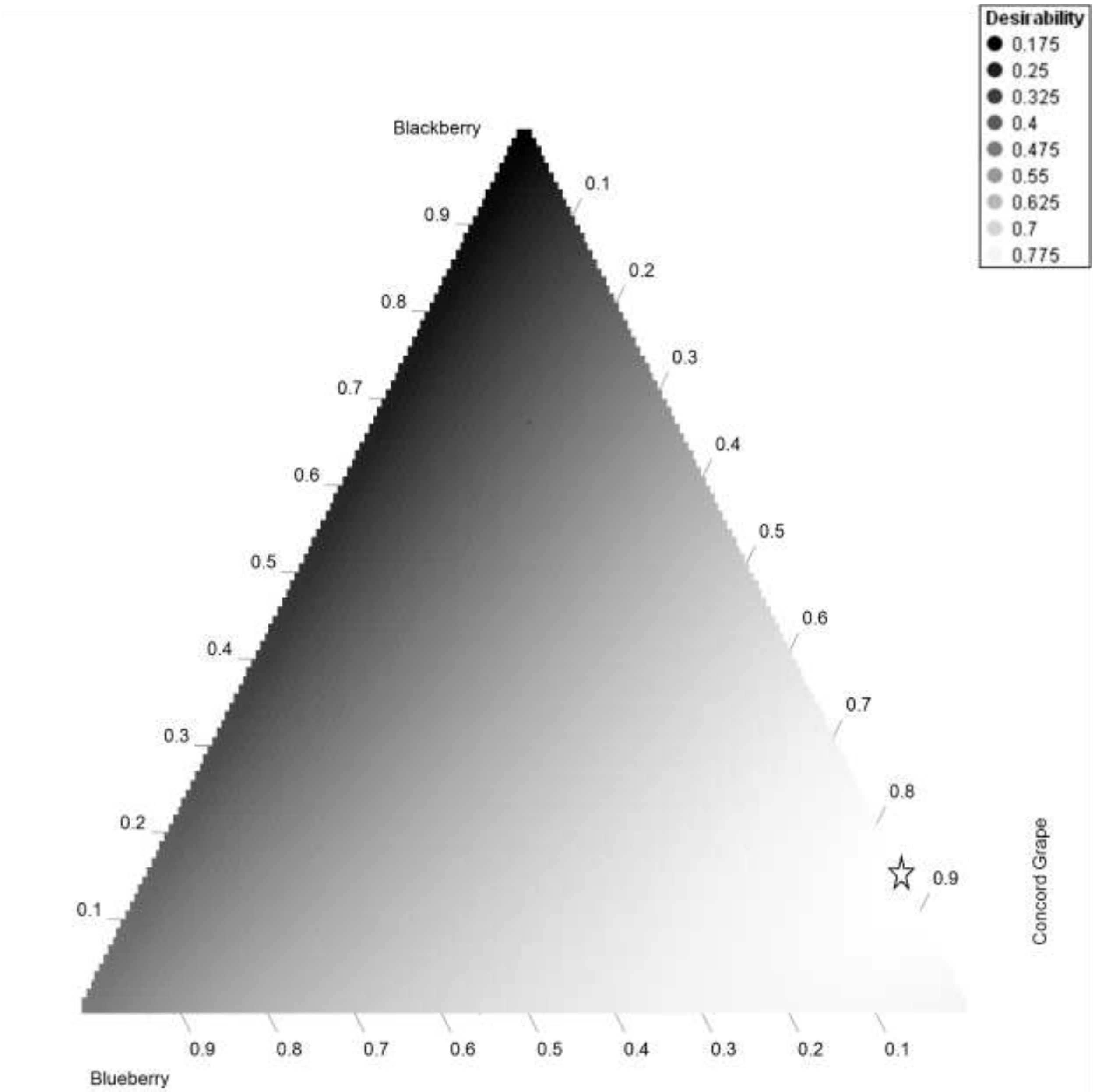


TABLE 4. POINTS OF HIGHEST DESIRABILITY (0.799)

Blackberry	Blueberry	Concord Grape
0.13	0	0.87
0.14	0	0.86
0.12	0	0.88
0.15	0	0.85
0.13	0.01	0.86
0.12	0.01	0.87
0.14	0.01	0.85
0.11	0	0.89
0.16	0	0.84
0.11	0.01	0.88

FIG. 6. VALIDATION STUDY DESIGN

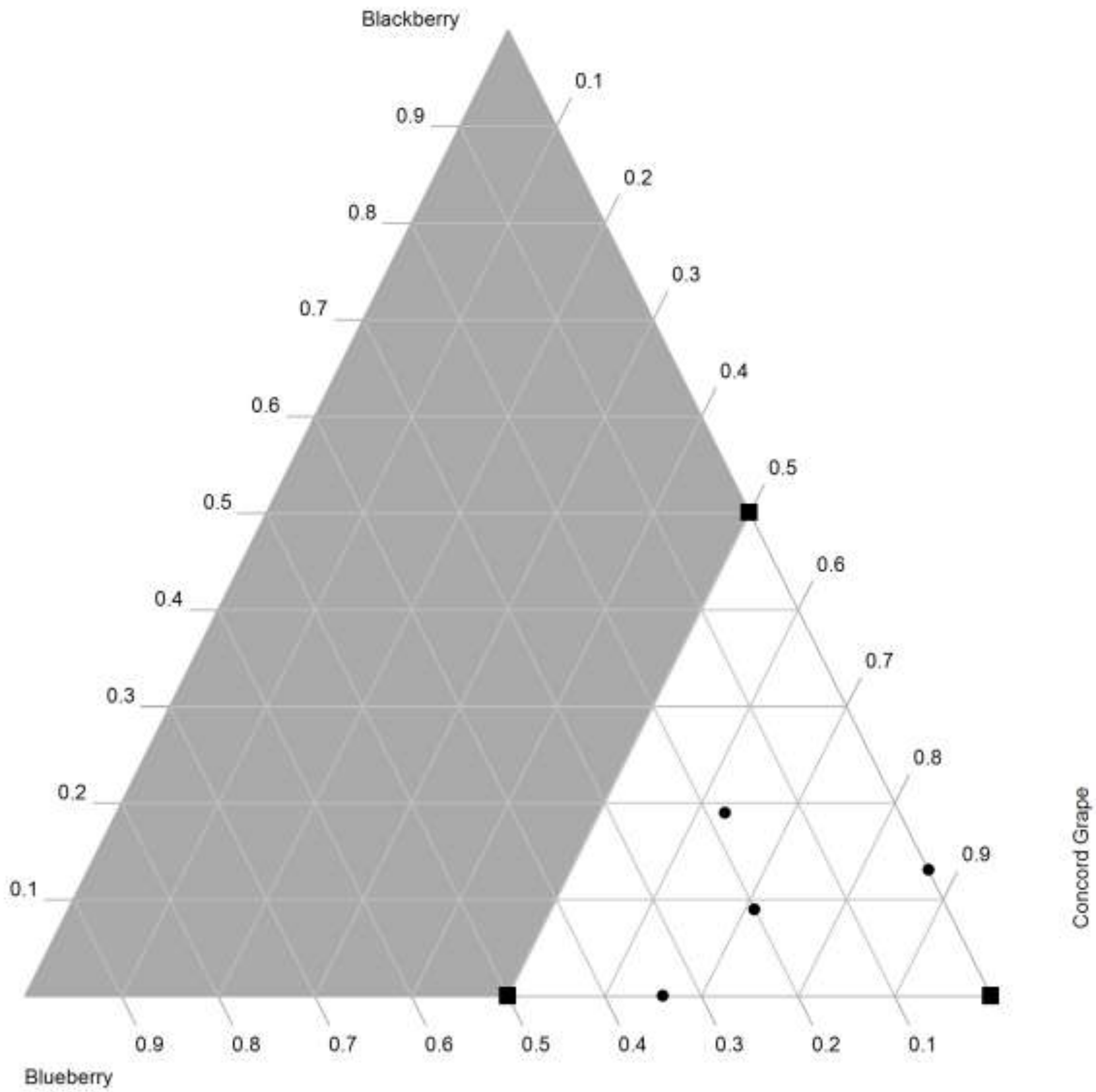


TABLE 5. OVERALL IMPRESSION MEANS FOR VALIDATION STUDY[a,b]

Optimization Method	Blend	Overall Impression Mean
Desirability function	13%Blk+87%Con	7.5a
Optima Framer	100%Con	7.3ab
Ideal point	9%Blk+20%Blu+71%Con	7.0ab
Intuitive Optimum	34%Blu+66%Con	6.9ab
Response Surface	19%Blk+18%Blu+63%Con	6.6b
Optima Framer	50%Blu+50%Con	6.3b
Optima Framer	50%Blk+50%Con	5.0c

[a]Means with different letter(s) for each attribute are significantly different ($p<0.05$) using Tukey's HSD difference method.
[b]Abbreviations: Blueberry (Blu), Blackberry (Blk), Concord grape (Con)

TABLE 6. CHANGING PURCHASE INTENT[a,b]

Optimization Method	Blend	Ranking (anthocyanin content)	Estimated Anthocyanin Content (mg/100ml)	Purchase Intent Directional Significance
Optima Framer	50%Blu+50%Con	1	39.3	↑
Optima Framer	50%Blk+50%Con	2	32.0	↑
Intuitive Optimum	34%Blu+66%Con	3	31.8	↑
Response Surface	19%Blk+18%Blu+63%Con	4	30.4	No significant difference
Ideal point	9%Blk+20%Blu+71%Con	5	28.2	No significant difference
Desirability Function	13%Blk+87%Con	6	20.2	↓
Optima Framer	100%Con	7	15.9	↓

[a]Abbreviations: Blueberry (Blu), Blackberry (Blk), Concord grape (Con)

[b]Directional significance determined by paired t-test at 0.05 significance level

FIG. 7. UPWARD SHIFT IN PURCHASE INTENT FOR 50%BLUEBERRY+50%CONCORD JUICE

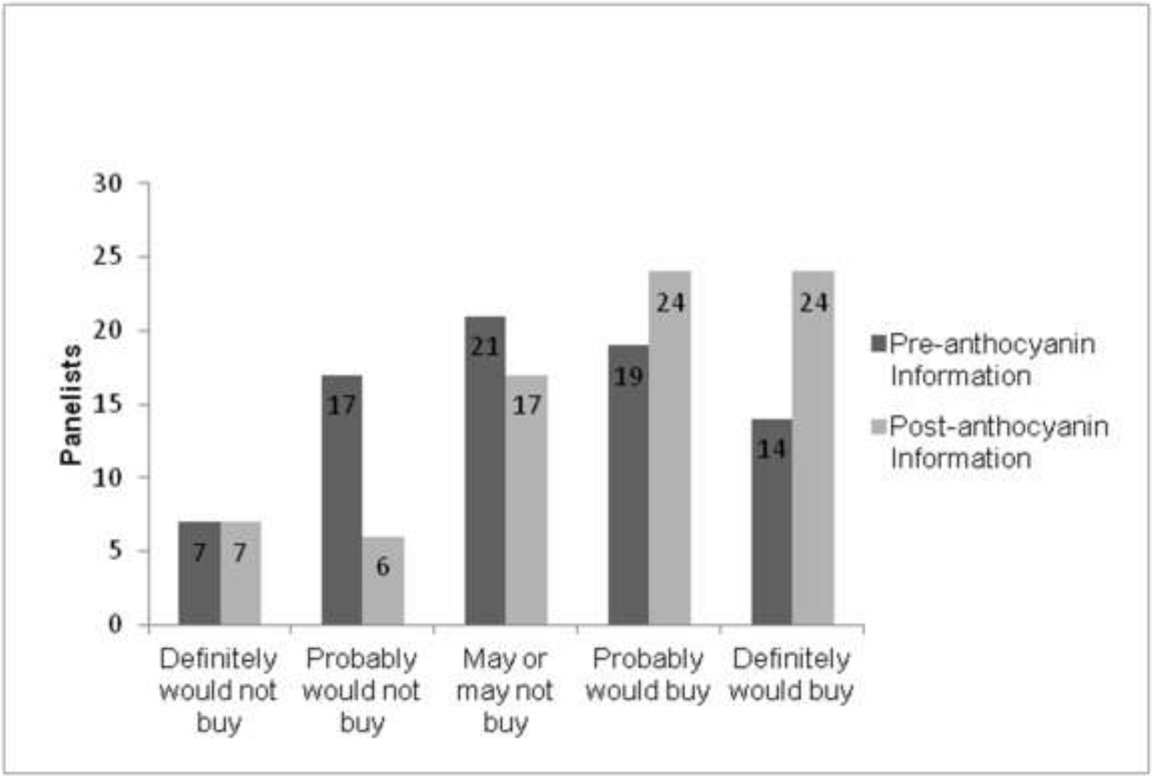
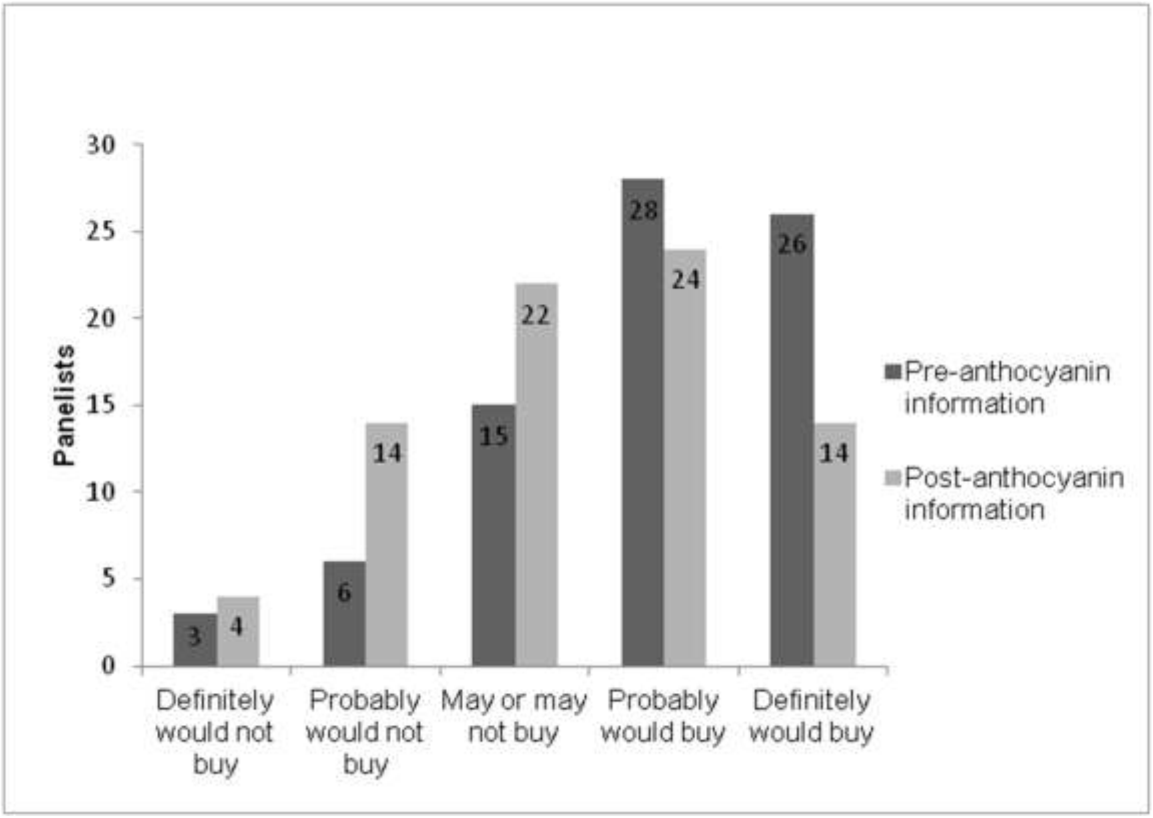


FIG. 8. DOWNWARD SHIFT IN PURCHASE INTENT FOR 100% CONCORD JUICE



CHAPTER 5

Willingness-To-Pay for a Nutraceutical-Rich Juice Blend

Lydia J. R. Lawless, Rodolfo M. Nayga, Jr., Faical Akaichi, Jean-François Meullenet,
Renee T. Threlfall, Luke R. Howard

Accepted Contingent upon Revision to the Journal of Sensory Studies

ABSTRACT

As human life expectancy increases, the potential for nutraceutical products expands. Economic theory and sensory science were integrated to determine 1) consumer acceptance of hypothetical health information and 2) the relative satisfaction consumers derived from sensory and nutraceutical characteristics of an optimized juice blend. Four non-hypothetical experimental auction sessions with 11-12 consumers/session were held (n=47) to elicit willingness-to-pay (WTP) for an optimized juice blend (87% Concord grape and 13% blackberry). Participants in two sessions tasted the product first and then received hypothetical health statements after the second round (vice versa for the other two sessions). Random effects regression showed WTP was higher when subjects tasted the product first and then received hypothetical health statements about anthocyanins, which indicates a contrast effect due to treatment order. Agreement with hypothetical health statements was not correlated to WTP. Nutraceutical product launch should be accompanied with taste sessions in stores to introduce consumers to product sensory properties.

PRACTICAL APPLICATIONS

Consumers' willingness-to-pay for nutraceuticals can be assessed through non-hypothetical experimental auctions. Non-hypothetical value elicitation methods use real money and products to advantageously eliminate hypothetical bias. Experimental auctions allow product attributes such as nutraceutical status to be assessed along with sensory characteristics; hence, auctions can more easily capture all product aspects that contribute to consumer liking. Understanding how consumers value all attributes can provide crucial information about a product's marketplace sustainability.

KEYWORDS auction, juice, willingness to pay, non-hypothetical, consumer

INTRODUCTION

In typical sensory testing with consumers, panelists are instructed to evaluate their acceptance of a product based on its sensory properties. However, products often possess non-sensorial attributes from which consumers also derive utility. Utilizing experimental auctions to measure willingness-to-pay (WTP) can determine how consumers value the sensorial and non-sensorial attributes of products. Experimental auctions and choice experiments have been used to determine the premium consumers are willing to pay for improved animal welfare, increased microbiological protection, and value-added nutraceutical characteristics (e.g., resveratrol-enhanced wine, conjugated-linoleic-acid-enhanced milk) (Napolitano *et al.* 2008, Nayga *et al.* 2006, Brown *et al.* 2005, Barreiro-Hurle *et al.* 2008, Maynard and Franklin 2003). Examples of experimental auctions applied to sensory components include comparing WTP and overall liking for champagne and determining the effects of sensory attributes on WTP for grass-fed beef (Lange *et al.* 2002; Xue *et al.* 2010). In this study, the experimental auction was applied to determine consumer valuations of an optimized grape and blackberry juice blend.

Experimental auctions are non-hypothetical value elicitation methods in which WTP values are elicited through incentive compatible measures (Jaeger *et al.* 2004), which ensure that participants' best bidding strategy is to bid their true WTP. Experimental auctions attempt to simulate real market situations in which consumers make the decision to buy a product and then purchase the product, which allows for the exchange of real money. Through this mechanism, the auction participant may incur real costs if s/he deviates from bidding his/her true WTP (Lusk and Hudson 2004). Hence, the WTP values obtained from experimental auctions can be more precise than those of other methods because they are non-hypothetical and are based on actual behavior instead of hypothetical intentions (Froehlich and Carlberg 2007). The method has great value in directing future research initiatives.

Several auction mechanisms have been developed including the Vickrey or second price auction, n^{th} price auction, and random n^{th} price auction. The structures, advantages, and disadvantages of these mechanisms, among others, has been discussed (Lusk and Shogren 2008). In the Vickrey auction, the highest bidder purchases the product with cash and pays the second highest bid, which allows the winner to purchase the product at a price below what s/he is willing to pay (Vickrey 1961). Underbidding and overbidding in this auction structure are not advantageous. Researchers may also utilize bidding rounds, which can elicit the learning effect in which consumers adjust to their true willingess-to-pay through experience with the auction (Shogren 2006). Only one round is randomly chosen as the binding round to prevent participants from bidding conservatively. Otherwise, auction participants may fear winning more than one round and paying for multiple products.

In this study, the experimental auction was applied to determine consumer valuations of an optimized Concord grape and blackberry juice blend. Dark-pigmented fruits such as nutraceutical-rich blackberries and Concord grapes contain phytochemicals. Anthocyanins, which impart the red-blue color to juices, have been linked to chemo-, neurological, and cardiovascular protective effects in vitro and in animal studies (Seeram *et al.* 2006; Folts 1998; Shukitt-Hale *et al.* 2009; Lila, 2004) . Although the Food and Drug Administration (FDA) does not approve health claims for anthocyanins (Food and Drug Administration 2011), understanding consumers' reactions to hypothetical health statements about anthocyanins can more efficiently direct future research in ways that will maximize consumer utility. Thus, the pilot study pursued here explores the effects of sensory properties and hypothetical health statements on consumer

WTP. The objectives of this study are 1) to assess the motivations behind and extent of consumer acceptance of hypothetical health statements and 2) to assess whether taste or health information has a greater impact on WTP and if the order in which taste and health information is presented affects WTP.

MATERIALS AND METHODS

Participants

Consumers were recruited from the University of Arkansas Sensory Center Database (n=5000). Forty-seven respondents (males=10, mean age=37, median income=42500) who reported to consume fruit juice at least three times per week and liked Concord grape and blackberry flavors were randomly selected to participate. Participants were compensated for their attendance in cash upon arrival to the Sensory Service Center before the experiment began.

Product

An optimized juice blend (13% blackberry+87% Concord grape), was created through a consumer evaluation (n=108) and a validation study (overall liking=7.5, n=78) using the verbal 9-point hedonic scale (unpublished observations). Consumers who participated in the auction did not participate in the optimization or validation studies. Juice production was described previously (Lawless *et al.* 2012 in press).

A half gallon (64 ounces) of the juice blend was auctioned in the experiment. Participants were also shown averaged reference prices for half gallons of white grape juice ($3.54) and orange juice ($3.00), which reminded consumers about substitute products available in the marketplace.

Experimental Design

The experimental auction was performed at the University of Arkansas Sensory Service Center with Institutional Review Board approval.

In order to familiarize subjects with the auction mechanism, a preliminary practice auction with three bidding rounds was performed with candy bars as the auctioned material. In each session, one bidding round was randomly chosen as binding. The winner in each session received one candy bar and paid the corresponding price.

In the experimental auction, there were four sessions of 11-12 subjects each (Figure 1). The number of panelists recruited was based on the amount of product available to auction. Each of these sessions consisted of four bidding rounds. During two sessions, the participants tasted the juice before the first bidding round and received a hypothetical health statement after the second bidding round. Participants in the other two sessions received a hypothetical health statement before the first bidding round and then tasted the juice after the second bidding round. Consumers evaluated two ounces of the juice blend in isolated tasting booths without replications. The hypothetical health statement shown to the consumers was as follows.
"You are bidding on a Concord grape and blackberry juice blend. Dark purple fruits such as Concord grapes and blackberries have been shown to contain anthocyanins. Anthocyanins are antioxidants, which have been shown in peer-reviewed studies to support better vision, defend against deterioration in brain performance due to aging, and prevent lipid oxidation that can promote obstructed arteries.[1] *"*

Since health claims for anthocyanins have not been formally approved by the FDA, the hypothetical health statement is not yet ready for commercial use.

---

[1] Excerpts from hypothetical health statements paraphrased from (Rice and Howard 2008).

After each bidding round, consumers submitted their anonymous bids to the moderator who was consistent throughout the experiment. The moderator wrote the identification number of the highest bidder and the second highest bid on the board. At the end of each session, one of the four bidding rounds was randomly chosen as the binding round through a drawing. After each auction session, panelists completed a computerized attitudinal and demographic questionnaire that contained 35 questions assessing important properties of nutraceutical juices, agreement with hypothetical health statements, lifestyle habits (e.g. juice consumption details, exercise frequency) , and basic demographic information. To assess attitudes and agreement with hypothetical health statements, consumers were asked to state their agreement to the statements (listed in Table 1) according to a five-category Likert scale in which *strongly agree* was assigned a value of five and *strongly disagree* a value of one. Consumers profiled their lifestyle habits and demographics through multiple choice and short answer questions.

Statistical Analysis

Correlations were performed using JMP® (version 9.0.2, Cary, NC, USA). Random effects regression and two sample t-tests were analyzed with Stata (version 11.0, College Station, TX, USA). Variables significant at $\alpha=0.05$ in the regression model were retained. Some attitudinal and demographic questions from the post-auction questionnaire were converted to dummy variables, while others were used without further preparation. In order to determine the significance of the order effect on WTP, a *Session* dummy variable was created in which participants who tasted and then received anthocyanin information were assigned a value of 1 and 0 otherwise.

RESULTS AND DISCUSSION

Assessing the motivations of consumer acceptance of hypothetical health statements

As part of the post-auction questionnaire, consumers were given a series of statements regarding the nutritional aspects of juice products and the believability of hypothetical health statements. Due to the limited scope of this study, the information collected was purposed to guide future research rather than to issue absolute conclusions. To assess correlations, the five-point Likert scale was assumed to be continuous. The practice of assuming an ordinal scale is continuous is sometimes used when evaluating affective data (e.g., (Dooley *et al.* 2012; Meullenet *et al.* 2008). Consumers may be more reliable when using categorical scales rather than continuous scales as suggested by Lawless *et al.* (2010) in comparing the categorical nine-point hedonic scale and the labeled affective magnitude line scale. Since consumers were being asked to respond to a series of potentially interrelated statements, categorical scales were used to promote consistency across the question set.

Correlations indicated significant relationships among hypothetical health statement agreement and general juice purchase behavior (Table 1). If consumers agreed that antioxidants have a positive effect on health, then they were likely to be willing-to-pay more for healthier foods (r=0.63) and to agree that anthocyanins can protect eye function (r=0.35). If consumers were accepting of juices sweetened with sugar, they tended to disagree that anthocyanins can promote eye function (r=-0.43). Consumers who were not opposed to juice being sweetened with high fructose corn syrup tended to not be opposed if juices were sweetened with sugar (r=0.56). They also did not agree that sugar was a more desirable sweetener than high fructose corn syrup (r=-0.42) or that they looked for products that claimed to be 100% juice (r=-0.46).

These consumers also disagreed that anthocyanins could protect eye function (r=-0.36) and that nutraceuticals could have a positive impact on health (r=-0.40).

For consumers that sought products that claimed to be 100% juice, they were likely to agree that anthocyanins could protect eye function (r=0.38) and reduce the risk of cancer (r=0.30) and that nutraceuticals could have a positive impact on health (r=0.47). If consumers agreed that anthocyanins could reduce the risk for heart disease, they likely believed that anthocyanins could reduce the risk for cancer (r=0.68) and protect eye function (r=0.44) and agreed that nutraceuticals could have a positive impact on health (r=0.60). Likewise, those who agreed that anthocyanins could reduce the risk for cancer also believed that anthocyanins could protect eye function (r=0.54) and that nutraceuticals could have a positive impact on health (r=0.57). Those who believed anthocyanins protected eye function also believed that nutraceuticals could have a positive impact on health (r=0.53).

Agreement with the eye function protection and cancer prevention statements did not correlate with agreement about the heart disease prevention statement. This could be due to the wording of the hypothetical health statement, which mentions prevention of obstructed arteries but does not explicitly mention "heart disease" or "heart health." Additionally, the information about obstructed arteries appears last in the hypothetical health statement, by which time, consumers could have lost interest in reading.

Generally, consumers who were more health conscious, as defined by those who looked for products that were 100% juice and who avoided added sweeteners, tended to be more accepting of hypothetical health statements. Consumers have been shown to be more accepting of health claims when the base product has a healthy connotation (Annunziata and Vecchio 2011). This could enable consumers to be more accepting of hypothetical health statements related to juice because of the inherent relationship of juice and fruit. Additionally, the type of health statement may contribute to consumer reactions toward nutraceutials. Some consumers were previously shown to be more receptive of nutrition and health claims rather than disease prevention claims (Verbeke *et al.* 2009), although other research suggests personal relevance to the disease reduction claim also contributes to its effectiveness (Dean *et al.* 2012). The hypothetical statement in this study was framed as a combination of a nutrition claim (i.e. statement that the product contains particular nutrients) and a health claim (i.e. description of the potential physiological action of the nutrient). Incorporating two types of claims could have widened consumer acceptance for the health information. The juice blend auctioned in this study was 100% juice and free of added sweeteners, which were important characteristics for consumers who were more accepting of hypothetical health statements.

Consumers who were more disbelieving of hypothetical health statements tended to be more accepting of both sugar and high fructose corn syrup as sweeteners. These consumers may view nutraceuticals (i.e., functional foods) as a marketing scam or feel that they have enough control over their own health that consuming functional foods is not needed (Verbeke *et al.* 2009). Furthermore, some consumers may feel that their current diet is healthy enough; thus, health is not weighted as heavily as sensory appeal, price, or convenenience in decision-making (Carrillo *et al.* 2011).

Interestingly, agreement or disagreement with any of the statements did not significantly correlate with WTP. Since the product was well-liked based on its sensory properties, even those who did not believe the associated hypothetical health statements may have equally desired the product based solely on its positive sensory properties. Additionally, health-associated characteristics may affect purchase intent more than WTP.

Assessing whether taste or health information has a greater impact on WTP

Across all bidding rounds and excluding one outlier, the mean WTP of the juice blend was $3.81, and the mean overall liking (based on a 9 pt. verbal hedonic scale) for the juice blend was 7.7, which suggests that the consumers in this study were open to natural, functional juice. Similarly, consumers were willing to pay for pear juice described as natural and other nutraceutical beverages including resveratrol-enhanced wine and conjugated linoleic acid-enhanced milk (Barreiro-Hurle *et al.* 2008, Maynard and Franklin 2003,Gracia *et al.* 2011), .

In order to compare the effects of tasting and hypothetical health statements on WTP, a two sample t-test was performed on means across all sessions of bids in rounds 1 and 2 (Table 2). Two sample t-test by treatment order on means across all sessions of bids in rounds 3 and 4 was also completed to identify the significance of the order effect (Table 3).

Initially, mean WTP was higher for participants who tasted the product first and then received health information than for participants who received the opposite treatment order. Individuals who tasted the product first may have had more confidence that the product would meet their sensory expectations post-purchase. This result is consistent with findings from studies involving consumers who tasted four individual tropical fruit juices (cajá, açaí, camu-camu, umbu) and others who tasted juices with varying levels of açaí and then received health information about the juices. In these studies, consumers expressed increased acceptance as information about the product increased (Vidigal *et al.* 2011, Sabbe *et al.* 2009). For other products such as yogurt and fermented milk, the effect of nutritional information on hedonic ratings differed by consumer segment (Bayarri *et al.* 2010). These studies are distinct from our study since they only tested one treatment order and measured consumer acceptance instead of WTP.

Those who received the hypothetical health statement first may have been conditioned to think that nutraceuticals are not as sensorially pleasing as non-nutraceuticals; thus, they were not confident that the product would meet their sensorial expectations. Prior research has shown that some consumers have a negative perception of the taste of nutraceuticals (i.e., functional foods) compared to non-nutraceuticals (Verbeke 2005). This perception could have contributed to reduced WTP for consumers who did not taste the product first.

The lower mean WTP for individuals who received hypothetical health statement first and then tasted the product indicates that introducing the health information first may have introduced a contrast effect that influenced subjects throughout the auction. Essentially, knowing that the product was healthy may have reduced expected liking and thus impacted actual liking. Expectation effects such as assimilation and contrast affected consumer acceptance in a study that explored the effects of taste and health information on consumer acceptance of pineapple, kiwi, kiwi “low calorie”, and hazelnut flavored soyamilk beverages (Behrens *et al.* 2007). Similar expectation effects could plausibly affect WTP along with consumer acceptance. T-test results suggest that the order of the treatments should not be ignored in future experimental auction designs.

Random effects regression was utilized to identify the important determinants of WTP for this group of consumers (Table 4).

Positive values for coefficients indicate effects that increase WTP.   The positive coefficient for *Session* indicates that WTP was higher when subjects tasted the product first and then received hypothetical health statements. This finding reinforces the t-test analysis in which there was evidence of a contrast effect due to order of the treatments. The results suggest that product launches should be accompanied with tastings (or other events or providing free samples) to completely introduce consumers to the product's sensory and functional properties.

Expectations for functional products may depend on consumer segment. Ares *et al.* (2010a) identified differing consumer segments and their expectations for an antioxidant-rich chocolate dessert. Some consumers were not bothered by sensory modifications to the product resulting from addition of antioxidants, while others who had high sensory expectations were disappointed by sensory changes. Additionally, some consumer segments are more interested in staying healthy than other segments, which affects their purchase intent for functional products, such as yogurt (Ares *et al.* 2010b). Expectations for nutraceuticals may influence how the product is ultimately perceived as the results suggest for the nutraceutical juice blend.

The positive coefficient for *Exercise* indicates that panelists who exercise three times per week or more were willing to pay more for the product than those who exercise less frequently. Individuals who exercised at a higher frequency may have been more health conscious and thus more interested in a potentially health beneficial juice blend. Health conscious population segments have been shown previously to be more accepting of health claims (Vidigal *et al.* 2011, Sabbe *et al.* 2009), which could explain health conscious individuals' increased interest in a potentially healthy product.

The significance of the round variables indicates that WTP increased throughout the auction, possibly due to the learning effect previously discussed in the introduction. As with the correlations, the auction procedure could be repeated with larger groups of consumers to increase the power of the regression results.

No demographic variables were significant predictors of WTP, which could partially be a result of the limited sample size in this study. For example, only 10 of the 46 subjects were male, and only 11 had a minimum education of a 4-year degree. Age and income were not necessarily affected by this limitation because these were considered continuous variables, which was possible because consumers were asked to indicate their exact ages and incomes rather than their age and income categories. Nevertheless, demographic variables were not included in the final model. Demographic variables such as children in household and education level (Barreiro-Hurle *et al.* 2008, Maynard and Franklin 2003) have been shown to influence WTP for functional beverages, although demographic determinants were not consistent across products or WTP elicitation methods. Some studies have shown that population segments such as women and elderly are more interested in nutraceuticals in general, but gender and age are not always significant predictors of WTP (Vidigal *et al.* 2011, Sabbe *et al.* 2009,Tuorila and Cardello 2002, Siegrist *et al.* 2008).

In general, the small number of participants in this pilot study liked the optimized blackberry and Concord grape juice blend, which supports the consumer validation study results completed previously (unpublished observations). Conjoint analysis has suggested that cost of probiotic nutraceuticals was slightly less important than the mode of delivery (i.e. product type) or the actual health claim associated with a nutraceutical, which suggests that improving the health claim associated with juice is an important focus of future work (Hailu *et al.* 2009).

Results have implications for product adoption and marketing strategies. Generally, consumers repeat purchase only if sensory expectations are met after the initial purchase (Di Monaco *et al.* 2004, Deliza and MacFie 1996). The role of meeting sensory expectations in purchase behavior may be expanded for products that are potentially nutraceutical-rich because of some consumers' general attitudes about the inferior taste of healthy foods. To overcome this bias, offering low-risk opportunities for consumers to taste nutraceutical products before the first purchase may increase WTP and the chance for market success. Alternatively, food and beverage manufacturers could make healthful adjustments to their products without informing the consumer, which eliminates the potential for consumers to decrease their acceptance and WTP for a product merely because that product contains healthful properties. However, product adjustments for health should not be made at the expense of sensory acceptance.

REFERENCES

ANNUNZIATA, A. and VECCHIO, R. 2011. Functional foods development in the European market: A consumer perspective. Journal of Functional Foods *3*, 223-228, DOI: 10.1016/j.jff.2011.03.011.

ARES, G., BARREIRO, C., DELIZA, R., GIMENEZ, A. and GAMBARO, A. 2010a. Consumer expectations and perception of chocolate milk desserts enriched with antioxidants. J. Sens. Stud. *25*, 243-260, DOI: 10.1111/j.1745-459X.2010.00293.x.

ARES, G., GIMENEZ, A. and DELIZA, R. 2010b. Influence of three non-sensory factors on consumer choice of functional yogurts over regular ones. Food. Qual. Prefer. *21*, 361-367, DOI: 10.1016/j.foodqual.2009.09.002.

BARREIRO-HURLE, J., COLOMBO, S. and CANTOS-VILLAR, E. 2008. Is there a market for functional wines? Consumer preferences and willingness to pay for resveratrol-enriched red wine. Food Quality and Preference *19*, 360-371, DOI: 10.1016/j.foodqual.2007.11.004.

BAYARRI, S., CARBONELL, I., BARRIOS, E.X. and COSTELL, E. 2010. Acceptability of yogurt and yogurt-like products: influence of product information and consumer characteristics and preferences. J. Sens. Stud. *25*, 171-189, DOI: 10.1111/j.1745-459X.2009.00271.x.

BEHRENS, J.H., VILLANUEVA, N.D.M. and DA SILVA, M.A.A.P. 2007. Effect of nutrition and health claims on the acceptability of soyamilk beverages. Int. J. Food Sci. Technol. *42*, 50-56, DOI: 10.1111/j.1365-2621.2006.01206.x.

BROWN, J., CRANFIELD, J.A.L. and HENSON, S. 2005. Relating consumer willingness-to-pay for food safety to risk tolerance: An experimental approach. Canadian Journal of Agricultural Economics-Revue Canadienne D Agroeconomie *53*, 249-263.

CARRILLO, E., VARELA, P., SALVADOR, A. and FISZMAN, S. 2011. Main Factors Underlying Consumers' Food Choice: a First Step for the Understanding of Attitudes Toward "Healthy Eating". J. Sens. Stud. *26*, 85-95, DOI: 10.1111/j.1745-459X.2010.00325.x.

DEAN, M., LAMPILA, P., SHEPHERD, R., ARVOLA, A., SABA, A., VASSALLO, M., CLAUPEIN, E., WINKELMANN, M. and LAHTEENMAKI, L. 2012. Perceived relevance and foods with health-related claims. Food Quality and Preference *24*, 129-135.

DELIZA, R. and MACFIE, H. 1996. The generation of sensory expectation by external cues and its effect on sensory perception and hedonic ratings: A review. J. Sens. Stud. *11*, 103-128, DOI: 10.1111/j.1745-459X.1996.tb00036.x.

DI MONACO, R., CAVELLA, S., DI MARZO, S. and MASI, P. 2004. The effect of expectations generated by brand name on the acceptability of dried semolina pasta. Food. Qual. Prefer. *15*, 429-437, DOI: 10.1016/j.foodqual.2003.07.003.

DOOLEY, L., THRELFALL, R.T. and MEULLENET, J.F. 2012. Optimization of blended wine quality through maximization of consumer liking. Food Quality and Preference *24*, 40-47.

FOLTS, J.D. 1998. Antithrombotic potential of grape juice and red wine for preventing heart attacks. Pharm. Biol. *36*, 21-27.

FOOD AND DRUG ADMINISTRATION 2011. Qualified Health Claims. http://www.fda.gov/Food/LabelingNutrition/LabelClaims/QualifiedHealthClaims/default.html (accessed July 20, 2011).

FROEHLICH, E. and CARLBERG, J.G. Comparing Willingness-to-Pay Estimates from Experimental Auctions with Mailed Surveys Incorporating Cheap Talk.

GRACIA, A., LOPEZ, B. and VIRUE, S. 2011. Willingness to pay for natural juice: a choice experiment approach. Itea-Informacion Tecnica Economica Agraria *107*, 21-32.

HAILU, G., BOECKER, A., HENSON, S. and CRANFIELD, J. 2009. Consumer valuation of functional foods and nutraceuticals in Canada. A conjoint study using probiotics. Appetite *52*, 257-265, DOI: 10.1016/j.appet.2008.10.002.

JAEGER, S.R., LUSK, J.L., HOUSE, L.O., VALLI, C., MOORE, M., MORROW, B. and TRAILL, W.B. 2004. The use of non-hypothetical experimental markets for measuring the acceptance of genetically modified foods. Food Quality and Preference *15*, 701-714, DOI: 10.1016/j.foodqual.2004.04.002.

LANGE, C., MARTIN, C., CHABANET, C., COMBRIS, P. and ISSANCHOU, S. 2002. Impact of the information provided to consumers on their willingness to pay for Champagne: comparison with hedonic scores. Food. Qual. Prefer. *13*, 597-608, DOI: 10.1016/S0950-3293(02)00059-9.

LAWLESS, L.J.R., THRELFALL, R.T., HOWARD, L.R. and MEULLENET, J.-. 2012 in press. Sensory, compositional, and color properties of nutraceutical-rich juice blends. American Journal of Enology and Viticulture *63*.

LILA, M. 2004. Anthocyanins and human health: An in vitro investigative approach. J. Biomed. Biotechnol. *2004*, 306-313.

LUSK, J. and SHOGREN, J.F. 2008. Experimental auctions: methods and applications in economic and marketing research. Cambridge University Press.

LUSK, J. and HUDSON, D. 2004. Willingness-to-pay estimates and their relevance to agribusiness decision making. Rev. Agric. Econ. *26*, 152-169, DOI: 10.1111/j.1467-9353.2004.00168.x.

MAYNARD, L.J. and FRANKLIN, S.T. 2003. Functional foods as a value-added strategy: The commercial potential of "cancer-fighting" dairy products. Review of Agricultural Economics *25*, 316-331.

MEULLENET, J.-F., LOVELY, C., THRELFALL, R., MORRIS, J.R. and STRIEGLER, R.K. 2008. An ideal point density plot method for determining an optimal sensory profile for Muscadine grape juice. Food Quality and Preference *19*, 210-219, DOI: 10.1016/j.foodqual.2007.06.011.

NAPOLITANO, F., PACELLI, C., GIROLAMI, A. and BRAGHIERI, A. 2008. Effect of information about animal welfare on consumer willingness to pay for yogurt. J. Dairy Sci. *91*, 910-917, DOI: 10.3168/jds.2007-0709.

NAYGA, R.M., JR., WOODWARD, R. and AIEW, W. 2006. Willingness to pay for reduced risk of foodborne illness: A nonhypothetical field experiment. Canadian Journal of Agricultural Economics-Revue Canadienne D Agroeconomie *54*, 461-475.

RICE, L.J. and HOWARD, L.R. 2008. Subcritical water and carbonated water extraction of anthocyanins from grape pomace. Discovery *9*, 82-90.

SABBE, S., VERBEKE, W., DELIZA, R., MATTA, V. and VAN DAMME, P. 2009. Effect of a health claim and personal characteristics on consumer acceptance of fruit juices with different concentrations of acai (Euterpe oleracea Mart.) RID F-8373-2010. Appetite *53*, 84-92, DOI: 10.1016/j.appet.2009.05.014.

SEERAM, N.P., ADAMS, L.S., ZHANG, Y., LEE, R., SAND, D., SCHEULLER, H.S. and HEBER, D. 2006. Blackberry, black raspberry, blueberry, cranberry, red raspberry, and strawberry extracts inhibit growth and stimulate apoptosis of human cancer cells in vitro. J. Agric. Food Chem. *54*, 9329-9339, DOI: 10.1021/jf061750g.

SHOGREN, J.F. 2006. Valuation in the lab. Environ. Resour. Econ. *34*, 163-172, DOI: 10.1007/s10640-005-3785-8.

SHUKITT-HALE, B., CHENG, V. and JOSEPH, J.A. 2009. Effects of blackberries on motor and cognitive function in aged rats. Nutr. Neurosci. *12*, 135-140, DOI: 10.1179/147683009X423292.

SIEGRIST, M., STAMPFLI, N. and KASTENHOLZ, H. 2008. Consumers' willingness to buy functional foods. The influence of carrier, benefit and trust. Appetite *51*, 526-529, DOI: 10.1016/j.appet.2008.04.003.

TUORILA, H. and CARDELLO, A.V. 2002. Consumer responses to an off-flavor in juice in the presence of specific health claims. Food Quality and Preference *13*, 561-569.

VERBEKE, W. 2005. Consumer acceptance of functional foods: socio-demographic, cognitive and attitudinal determinants. Food Quality and Preference *16*, 45-57, DOI: 10.1016/j.foodqual.2004.01.001.

VERBEKE, W., SCHOLDERER, J. and LAHTEENMAKI, L. 2009. Consumer appeal of nutrition and health claims in three existing product concepts. Appetite *52*, 684-692, DOI: 10.1016/j.appet.2009.03.007.

VICKREY, W. 1961. Counterspeculation, auctions, and competitive sealed tenders. J. Finance *16*, 8-37.

VIDIGAL, M.C.T.R., MINIM, V.P.R., CARVALHO, N.B., MILAGRES, M.P. and GONCALVES, A.C.A. 2011. Effect of a health claim on consumer acceptance of exotic Brazilian fruit juices: Acai (Euterpe oleracea Mart.), Camu-camu (Myrciaria dubia), Caja (Spondias lutea L.) and Umbu (Spondias tuberosa Arruda). Food Res. Int. *44*, 1988-1996, DOI: 10.1016/j.foodres.2010.11.028.

XUE, H., MAINVILLE, D., YOU, W. and NAYGA, R.M., JR. 2010. Consumer preferences and willingness to pay for grass-fed beef: Empirical evidence from in-store experiments. Food. Qual. Prefer. *21*, 857-866, DOI: 10.1016/j.foodqual.2010.05.004.

FIG. 1. EXPERIMENTAL AUCTION DESIGN

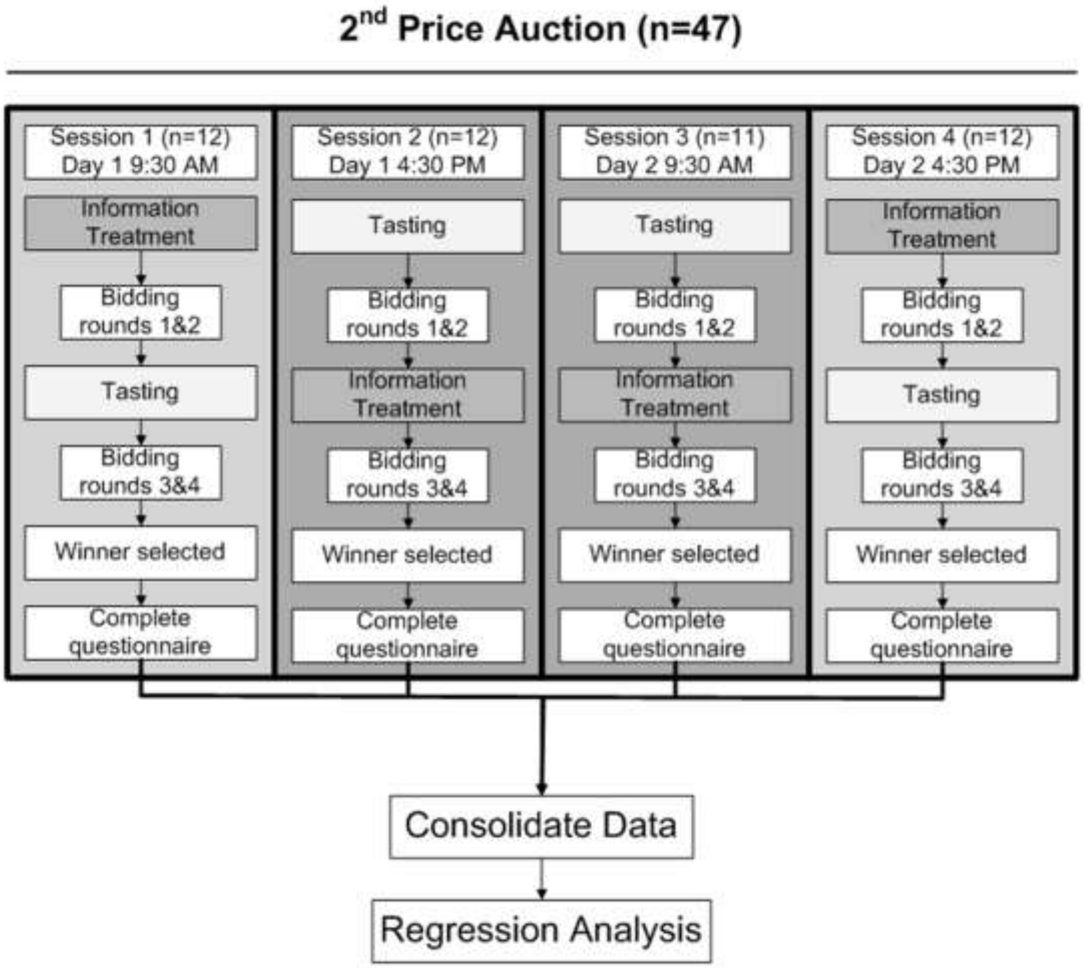


TABLE 1. HYPOTHETICAL HEALTH STATEMENT AGREEMENT BY CORRELATIONS[a]

	Antioxidants	Pay more	Sugar	HFCS	HFCS vs. table sugar	100% juice	Heart Disease	Cancer	Eye Function	Nutra-ceuticals	WTP
Antioxidants are beneficial to my health. (Antioxidants)	1.00	-	-	-	-	-	-	-	-	-	-
I am willing to pay more for more expensive fruit juices that are healthier for me. (Pay more)	0.63***	1.00	-	-	-	-	-	-	-	-	-
I do not mind if fruit juices are sweetened with sugar. (Sugar)	-0.13	-0.16	1.00	-	-	-	-	-	-	-	-
I do not mind if fruit juices are sweetened with high fructose corn syrup. (HFCS)	-0.08	-0.01	0.56***	1.00	-	-	-	-	-	-	-
In sweetened fruit juices, high fructose corn syrup is a less desirable sweetener than table sugar. (HFCS vs. table sugar)	-0.23	-0.25	-0.08	-0.42**	1.00	-	-	-	-	-	-
I look for products that claim to be 100% juice. (100% juice)	0.12	0.14	-0.19	-0.46**	0.02	1.00	-	-	-	-	-
Consuming fruits high in anthocyanins will reduce my risk of heart disease. (Heart disease)	0.09	0.04	-0.22	-0.18	0.03	0.22	1.00	-	-	-	-
Consuming fruits high in anthocyanins will reduce my risk of cancer. (Cancer)	0.20	0.09	-0.18	-0.27	-0.11	0.30*	0.68***	1.00	-	-	-
Consuming fruits high in anthocyanins will protect my eye function. (Eye Function)	0.35*	0.43**	-0.43**	-0.36*	-0.20	0.38**	0.44**	0.54***	1.00	-	-
Consuming nutraceuticals can have a noticeable positive impact on my health. (Nutraceuticals)	0.28	0.23	-0.27	-0.40**	0.05	0.47***	0.60***	0.57***	0.53***	1.00	-
Mean WTP/person across all bidding rounds (WTP)	0.09	0.25	-0.16	0.13	0.05	-0.17	0.02	-0.14	-0.02	0.02	1.00

[a]*, **, *** Indicates significance at $p<0.05$, $p<0.01$, $p<0.001$, respectively based on $n=506$ observations

TABLE 2. TWO SAMPLE T-TEST BY TREATMENT (ROUNDS 1 & 2)[a]

Treatment	**Mean Willingness-to-pay (Rounds 1 & 2)**
Taste[b]	3.58a
Hypothetical Health Statement[c]	3.27b

[a]Letters denote significant differences (Two sample t-test, α=0.10)
[b]Consumers evaluated the juice blend based on its sensory properties.
[c]Consumers received the hypothetical health statement.

TABLE 3. TWO SAMPLE T-TEST BY TREATMENT ORDER (ROUNDS 3&4)[a]

Treatment	**Mean Willingness-to-pay (Rounds 3 & 4)**
Taste to Hypothetical Health Statement[b]	4.01a
Hypothetical Health Statement to Taste[c]	3.56b

[a]Letters denote significant differences (Two sample t-test, $\alpha=0.10$)
[b]Consumers evaluated the juice blend based on its sensory properties before they received the hypothetical health statement.
[c]Consumers received the hypothetical health statement before they evaluated the juice blend based on its sensory properties.

TABLE 4. RANDOM EFFECTS REGRESSION RESULTS (ROUNDS 1, 2, 3, 4)[a,b]

Variable Name	**Coefficient**	**P-Value**
Session[c]	0.63	0.001
Exercise[d]	0.54	0.006
Round 2 [e]	0.34	<0.001
Round 3 [e]	0.71	<0.001
Round 4 [e]	0.93	<0.001

[a]Response variable in model is willingness-to-pay.
[b]Model fit indicator: Wald statistic (145.11)
[c]Dummy variable in which participants in sessions 2 and 3 were assigned 1 and 0 otherwise.
[d]Dummy variable in which subjects who exercised 3+ times/week were assigned 1 and 0 otherwise.
[e]Dummy variable in which round x was given a value of 1 and 0 otherwise.

CHAPTER 6

Screening Nutraceutical-Rich Juices with Choice Designs

Lydia J. R. Lawless, Renee T. Threlfall, Jean-François Meullenet

Formatted for submission to the Journal of Sensory Studies

ABSTRACT

Research and development of nutraceuticals is increasing as the market expands. The potential health benefits of anthocyanin- and proanthocyanidin-rich fruits such as açaí, black cherry, blueberry, Concord grape, cranberry, and pomegranate make the juices of these fruits prime sources of nutraceuticals. Juice blending maximizes positive juice attributes and minimizes negative attributes (e.g., bitterness, astringency) to create optimized juice blends with balanced sensory and nutraceutical characteristics. Using computer surveys, participants (n=1291) completed 38 choice exercises concerning their preferred juice blends (i.e., three-component blends composed of açaí, black cherry, blueberry, Concord grape, cranberry, and/or pomegranate juice). Participants considered antioxidant information about each of the individual juices and their estimated acceptance of the juice blend based on anticipated sensory properties. The *black cherry, Concord grape, and pomegranate* juice blend received the highest marginal utility (x=0.51) and thus was the most suitable for further optimization. Choices were mostly driven by overall liking for each juice blending component and juice antioxidant information.

PRACTICAL APPLICATIONS

Screening designs are necessary to maximize research resource potential and to select the most suitable products for further development. A screening choice design was applied to narrow the range of juice blends to the one most suited for further optimization. Similar screening designs can be used for other products to facilitate the selection of the best profiles.

KEYWORDS

Juice, nutraceutical, choice, consumer, survey, familiarity

INTRODUCTION

Product development of nutraceuticals has increased recently due to the growing demand for health-oriented products. Choice exercises have been applied to narrow possible prototypes to product profiles most likely to maximize consumer utility (i.e., satisfaction received from consuming a good or service) (Krystallis *et al.* 2010, Frata *et al.* 2009, Hailu *et al.* 2009). Nutraceutical-rich fruit juice blends are good candidates for the expanding nutraceutical market because of their inherent healthfulness and convenience (Gracia *et al.* 2011, Annunziata and Vecchio 2011, Siegrist *et al.* 2008).

Seeram *et al.* (2008) determined the antioxidant composites of nutraceutical-rich wine, tea, and fruit juice. Fruit juices such as Concord grape, blueberry, black cherry, açaí, and cranberry have higher antioxidant capacity than orange juice, iced tea, and apple juice and potentially are more accessible than red wine due to government regulation of alcohol. Pomegranates, Concord grapes, blueberries, black cherries, açaí berries, and cranberries are high in polyphenolics, which potentially have antioxidative, antimutagenic, and anticarcinogenic effects (Folts 1998, Seeram *et al.* 2006, Seeram *et al.* 2006, Goyarzu *et al.* 2004, Burin *et al.* 2010, O'Byrne *et al.* 2002, Guo *et al.* 2008, Guo *et al.* 2008, Lansky *et al.* 2005, Cho *et al.* 2004, Del Pozo-Insfran *et al.* 2006, Kim *et al.* 2005). Three component juice blends have been used for optimization (Dooley *et al.* 2012, Gacula 1993).

Many consumer characteristics influence preferences for nutraceutical products. Studies have shown that demographics such as gender and age are associated with preferences for particular carrier-functional ingredient combinations (i.e., combination of the base product and its functional ingredient) (Ares and Gambaro 2007). Other studies have indicated that women and elderly are more interested in nutraceutical-rich foods, although the reported effects are often marginal (Siegrist *et al.* 2008, Dean *et al.* 2012, Ares *et al.* 2009, Ares *et al.* 2008b, Sabbe *et al.* 2009,Verbeke *et al.* 2009). Attitudinal and lifestyle variables tend to better predict acceptance of nutraceuticals (i.e., functional foods). Familiarity with the product, general knowledge about nutrition, and perceived personal knowledge about functional foods positively influenced nutraceutical acceptance (Verbeke *et al.* 2009, Ares *et al.* 2008a, Lahteenmaki *et al.* 2010). Additionally, personal relevance to the health claim and general interest in healthy eating promoted favorable product reception (Dean *et al.* 2012). Consumers who felt they had control over their health or that functional foods were a marketing scam were less accepting of functional food concepts (Verbeke *et al.* 2009).

Time preference is an attitudinal variable that considers the level of future orientation an individual possesses (Chapman 2003, Frederick *et al.* 2002). Highly future-oriented individuals invest more cognitive effort into preparing for the future, while other individuals are more present-oriented. Conceivably, individuals who are highly future-oriented will be more likely to accept nutraceutical products that may aid in extending their healthy years; however, time preference has not yet been addressed in the nutraceutical literature. Time preference is assessed in this study with agreement/disagreement to the statement *I live life one day at a time and don't think much about the future,* which has been used in previous studies as a time preference indicator (Sloan *et al.* 2009, Ayyagari *et al.* 2011). The significance of the time preference indicator may aid in determining whether time preference should be included in future nutraceutical attitudinal studies. Using a screening design to identify the juice blends most suitable for further development is necessary to optimize research resources.

The objectives of this study were 1) to utilize a choice design to select the best juice blend for further optimization and 2) to identify preference, demographic, lifestyle, or attitudinal factors that influence juice blend choice. The juice optimization procedure that occured post-screening-design was presented in a companion paper entitled *Applying a mixture design to consumer optimization of black cherry, concord grape, and pomegranate juice blends*.

MATERIALS AND METHODS

Participants

Participants from the University of Arkansas Sensory Service Center Database (n=5513) were invited to participate in their randomly assigned screening survey block via a web survey administered through Survey Monkey. Participants were offered a chance in a random drawing for gift cards to complete the survey. Most participants were female (n=723), had a median income of $25000-$74999 (n=565), and were over the age of 36 (n=599) (Table 1).

Survey Design

Participants (n=1291) were introduced to the survey by the following information. Antioxidant information was based on previous work (Seeram *et al.* 2008).

> *For the survey below, imagine you are shopping at the grocery store for a fruit juice blend. In each question, choose your most preferred blend. Consider how you think the juice would taste and the following information about antioxidants.*
>
> *Pomegranate juice is highest in antioxidants.*
> *Concord grape juice is second highest in antioxidants.*
> *Blueberry juice is third highest in antioxidants.*
> *Black cherry, açaí, and cranberry tie for the fourth highest in antioxidants.*

Two three-component juice blends were presented to consumers in each choice question, which created 190 possible choice questions (Figure 1). Pilot surveys indicated that presenting 190 choice questions to a single panelist was too arduous but that 30-40 choice questions was an appriopriate range.   Therefore, 190 possible choice questions were divided into five blocks so that each panelist only completed 38 choice questions. Panelists were randomly assigned to each block, and questions within blocks were randomized for each panelist. There were over two hundred completed surveys in each block with the fewest completed surveys in Block 5 (x=207). To balance the design across blocks, 207 completed surveys were randomly selected from each of the remaining blocks.

Besides the choice exercises, participants were asked about liking and consumption frequency for each individual blending component. Additionally, demographic and lifestyle questions such as exercise frequency, gender, age, education, income, and size of household were administered. Participants also used a 7-point Likert scale anchored by *very strongly agree* and *very strongly disagree* to answer two attitudinal statements, 1) *Antioxidants are beneficial to my health* and 2) *I live life one day at a time and don't think much about the future*. The former measured acceptance of health information and has been used in previous studies within the University of Arkansas Sensory Service Center (Lawless *et al.* 2012, in press a). The latter proxied time preference and has been used in previous literature (Sloan *et al.* 2009, Ayyagari *et al.* 2011).

Statistical Analysis

Frequencies were assessed for juice blends and individual juices. Choice model analysis was performed with choice as the binary response variable and juice blend as the independent variable. Covariates such as overall liking for the individual components and demographics were also tested in the model. Pairwise correlations were performed on estimated average unfamiliarity, estimated average liking, binary variables which represented the presence of individual components, and frequency choices of juice blends. Hierarchical cluster analysis using Ward's criterion was performed on marginal utility to determine groups of similar juice blends. Most analysis was done with (JMP 9.0.2 Cary, NC). Partial least squares regression-1

(PLSR) was performed using cross validation uncertainty test on two separate models (Unscrambler X 10.1, Camo, Woodbridge Township, New Jersey). The data matrix for the model with marginal utility as the response and blending components as predictors was not standardized before analysis. The data matrix for the model with marginal utility as the response and estimated average unfamiliarity, estimated average liking, and average antioxidant ranking as predictors was standardized before regression was performed.

RESULTS AND DISCUSSION

Frequency

Black cherry, Concord grape, and pomegranate was the most frequently chosen juice blend (Figure 2). Of the top 10 blends, eight contained pomegranate, six contained Concord grape, four contained cranberry, four contained black cherry, three contained blueberry, and two contained açaí. Concord juice, pomegranate juice, and cranberry juice were the most recently consumed by the majority of participants (Table 2). About 76% of participants (n=782) consumed Concord grape juice, 77% (n=794) consumed cranberry juice, and 64% (n=661) consumed pomegranate juice in the last 30 days. In comparison, 50% (n=522) consumed açaí juice, 49% (n=504) consumed black cherry juice, and 50% consumed (n=513) blueberry juice in the last 30 days. Familiarity contributes to acceptance of nutraceuticals, which could have contributed to the high frequency of Concord, pomegranate, and cranberry juices in the top ten juice blends (Sabbe *et al.* 2009, Krutulyte *et al.* 2011).

Concord, cranberry, and pomegranate juices were the most recently consumed by the majority of participants. These juices also received the highest overall liking scores (Table 3). Familiarity also seemed to be related to overall liking scores because fruit juices that had high overall liking scores (e.g., Concord grape, cranberry, pomegranate) tended to be the ones most frequently consumed. Additionally, pomegranate and Concord juices were the highest and second highest in antioxidants. Although sensory quality is the number one factor in nutraceutical juice acceptance, health information can increase overall liking and/or purchase intent (Lawless *et al.* 2012 in press b, Sabbe *et al.* 2009), which may have been the case for pomegranate and Concord juice in this survey.

Pomegranate was the most frequently chosen fruit within the blends (Figure 3). Concord was the second most frequently chosen, followed by cranberry, black cherry, blueberry, and açaí. As previously discussed, the high frequencies of pomegranate and Concord grape juices may have been due to a combination of familiarity and positive reinforcement from the antioxidant information. Similarly, the mid-frequency of cranberry could be due to familiarity and its associated overall liking score (Tables 2 and 3). The mid-frequency of black cherry is less clear since it was not highly familiar and tied for fourth highest in antioxidants. Although, black cherry juice could have been attractive because cherries are generally associated with being sweet. Sweetness is a strong driver of liking in juice blends in particular (Lawless *et al.* 2012 in press b, Drossard *et al.* 2012). The overall liking score for black cherry is tied with pomegranate juice for third highest, which could be due in part to the perception that cherries are sweet fruits.

Blueberry and açaí juices were not as frequently chosen as the other juices. Food neophobia (i.e., fear of new foods) has been shown to explain some differences among consumers' acceptance of açaí and novel products in general (Menezes *et al.* 2011,Vidigal *et al.* 2011, El Dine and Olabi 2009). Similarly, the low familiarity for blueberry juice (Table 2) could have interfered with the potential acceptance of blueberry-containing juices. Previous work has shown marginal hedonic scores for blueberry juice in part because of its low sweetness level (Lawless *et al.* 2012 in press b). Blueberry was most likely not chosen often because many consumers were not familiar with blueberry juice, and those that were may have only marginally accepted blueberry juice. A combination of familiarity, perceived sensory attributes, and antioxidant information could have influenced choice for juice blends.

Pairwise Correlations

In order to understand the influence of familiarity, overall liking, and the frequency individual components were chosen, pairwise correlations were performed on dummy variables for the individual components, estimated average liking (Equation 1), and estimated average familiarity (Equation 2) (Table 4).

Eq 1. (Overall liking (x) + Overall liking (y) + Overall liking (z)/3)= Estimated Average Liking

Eq 2. (Frequency Never Consumed (x) + Frequency Never Consumed (y) +Frequency Never Consumed (z)/3)=Estimated Average Unfamiliarity, where

Frequency Never Consumed= Frequency of sampled population who has never consumed a particular component.

Scores for overall liking for blends were estimated based on scores from individual components to avoid the high cognitive effort that would be required if consumers evaluated overall liking on twenty hypothetical blends. Similarly, familiarity was averaged from individual components due to the blends' lack of availability in the marketplace.

Estimated average unfamiliarity is negatively correlated to estimated average liking (r=-0.86), which supports previous research that found familarity influences reported liking for nutraceutical beverages (e.g., calcium fortified drink, green tea) (Tuorila *et al.* 2008, Lee *et al.* 2010). Estimated average liking is positively correlated to the presence of Concord juice (r=0.78) and cranberry juice (r=0.36) as blending components but not to the others. Since Concord and cranberry juice were the second and third most frequently chosen juice blend components, the positive correlation is expected. Estimated average liking being negatively correlated to the presence of pomegranate juice (r=-0.19), the most frequently chosen blending component, is unexpected, although it could be explained by the relatively weak correlation and/or antioxidant status of pomegranate. Perhaps pomegranate does not have the most well-liked sensory attributes among the blending components, but it has the highest antioxidant composite, which could have influenced consumer choice.

For some consumers, there is a tradeoff between sensory properties and health benefits as long as the sensory properties remain acceptable. Previously, some health claims increased liking for products with off-flavors; however, liking decreased as the off-flavor increased (Tuorila and Cardello 2002). Similarly, consumer purchase intent for blackberry, blueberry, and Concord grape juice blends was measured before and after consumers received information about their potentially health-beneficial anthocyanins. For the three juice blends highest in anthocyanins (50%blackberry+50%Concord grape, 50%blueberry+50%Concord grape, and 34%blueberry+66%Concord grape), purchase intent increased post-information; however, for the least-liked sample (50%blackberry+50%Concord grape), average purchase intent only increased to 2.55 on a 5-point scale anchored by *definitely would not buy* (1) and *definitely would buy* (5). The health information increased purchase intent, but it could not compensate fully for the product's undesirable sensory properties (Lawless *et al.* 2012, in press b). Likewise, health information for camu-camu juice increased product acceptance, but the overall liking score remained in the unacceptable range (Vidigal *et al.* 2011). Sensory properties are most important for product acceptance, although health information potentially supports overall liking and purchase intent of juice.

Choice Model Analysis

The choice model was built on a binary response variable and predictors that included the juice blend attribute (20 levels) and liking for each individual component. The liking variable captures familiarity/unfamiliarity because individuals who indicated they had never tried a blending component were assigned a liking score of 0 for that variable. Initial models indicated that demographic and lifestyle variables such as exercise frequency, income, gender, and age did not influence choice. Similarly, agreement or disagreement with the statement *Antioxidants are beneficial to my health* and *I live life one day at a time and don't think much about the future* did not influence choice for juice blends. Therefore, the final model contained only overall liking variables (Table 5). Estimates are shown for each juice blend and the interaction between each juice blend and overall liking of each component. The estimate represents the contribution to utility of the indicated effect. For example, the estimates related to *blueberry, cranberry, and pomegranate* are positive for overall liking of blueberry, cranberry, and pomegranate while the estimates for overall liking of the other three components not present in the blend are negative.

The absence of effects from demographic and attitudinal variables was not predicted by previous literature. However, different aspects of attitude were measured in the current study. Time preference, not personal relevance to health claim or personal knowledge about nutritional foods, was addressed (Dean *et al.* 2012, Ares *et al.* 2008a). Other research has found that general interest in healthy eating is predictive of functional food acceptance (Dean *et al.* 2012). Agreement to *Antioxidants are beneficial to my health* may be associated with this attitude; however, there was high agreement to this statement across subjects. Specifically, 93% (n=958) participants agreed with the statement; 42% (n=453) very strongly agreed. Possibly, there was too much homogenity in this variable to produce significance.

Marginal Utilities

Choice model analysis indicated that *black cherry, Concord grape, and pomegranate* and *Concord grape, cranberry, and pomegranate* juice blends had the highest and second highest marginal utilities (0.51 and 0.49 respectively) (Table 6). Marginal utilities for blends such as *black cherry, Concord grape, and pomegranate* and *Concord grape, cranberry, and pomegranate* were high because mean overall liking was higher for components such as Concord, cranberry, and pomegranate and lower for açaí.

Black cherry, Concord grape, and pomegranate was chosen as the blend most suited for optimization; however, both *black cherry, Concord grape, and pomegranate* and *Concord grape, cranberry, and pomegranate* could be further developed due to the similarity of their marginal utilities (0.51 and 0.49 respectively).

In order to identify the distance between different groups of juice blends, cluster analysis was performed on marginal utilities (Table 6). In the four cluster solution, cluster 1 contains blends with Concord grape and pomegranate accompanied by either of the next most desirable blending components, Concord grape or cranberry. Cluster 2 contains pomegranate and Concord blends with either of the least desirable blending components, blueberry or açaí. Cluster 2 also has blends that contain either pomegranate or Concord grape juice but not both and that are accompanied by either black cherry or cranberry juice. Cluster 3 mostly contains blends that contain either Concord grape or pomegranate juice accompanied by the less frequently chosen blueberry or açaí juices. Cluster 4 contains blends with the least frequently chosen components, açaí and/or blueberry juice, and no pomegranate juice at all. Cluster analysis suggests that pomegranate and Concord grape juices are important for attaining high marginal utility and that açaí and blueberry juices detract from high marginal utility.

Partial Least Squares Regression on Important Factors

The importance of each blending component on juice blend marginal utility was determined using PLSR (Figure 4). The prediction variables were binary variables, which indicated whether or not a blending component was present in a blend. The response variable was marginal utility. High, positive coefficients for pomegranate (0.37) and Concord grape (0.16) indicated that these blending components supported utility. The coefficient for black cherry was significant (-0.07) but near 0, which denotes a marginal effect. The coefficient for cranberry (0.03) was near 0 and not significant, which implies a neutral blending component. Coefficients for açaí (-0.34) and blueberry (-0.15) were negative, which suggests that these components detracted from high utility. Overall, Concord grape and pomegranate juice were important for utility, black cherry and cranberry had neutral to marginal effects, and blueberry and açaí decreased utility. Similar patterns were observed in cluster analysis and frequency counts.

Marginal utility was the response, and estimated average liking, estimated average unfamiliarity, and average antioxidant ranking were predictors in the second PLSR model (Figure 5). All effects were significant; however, the coefficients for average antioxidant ranking (-0.38) and estimated average liking (0.19) showed a stronger effect on utility than the coefficient for estimated average unfamiliarity (-0.01). Blends that had higher estimated overall liking scores and better average antioxidant ranking scores supported utility. The coefficent for average antioxidant ranking is negative because average rankings closer to one (and farther from four) represent better ranking scores.

According to PLSR, overall liking and antioxidant information are more important than unfamiliarity for utility of juice blends. The small effect of unfamiliarity/familiarity on utility seems to contrast previous literature, which supports correlations between product acceptance scores and familiarity (Krutulyte *et al.* 2011,Tuorila *et al.* 2008, Lee *et al.* 2010). However, the unfamiliarity in the current study was estimated based on self-reported consumption frequency. Other studies have examined familiarity other ways. As examples, ratings for liking and pleasantness were compared for familiar and unfamiliar foods, and acceptance of products was examined for populations with varying levels of experience with the product (Tuorila *et al.* 2008, Lee *et al.* 2010). As another example, an expert panel rated the market familiarity of food carrier-functional benefit combinations; the experts' ratings were compared to consumer purchase intent and perceived fit of the combination (Krutulyte *et al.* 2011). Differences in the measuring tool or the aspect of familiarity measured could account for the findings.

CONCLUSIONS

Overall liking and antioxidant ranking for each blending component were strongly associated with the juice blends chosen. The choice exercise was effective in screening many product profiles to identify the juice blends most suitable for further optimization. Specifically, *black cherry, Concord grape, and pomegranate* and *Concord grape, cranberry, and pomegranate* were identified as potential juice blends to optimize. The reasons that these blends were chosen were related to multiple factors such as 1) pomegranate and Concord grape juices having the highest antioxidants; 2) Concord grape, cranberry, pomegranate, and black cherry juices receiving the highest overall liking scores; and 3) Concord grape, cranberry, and pomegranate juices being most recently and frequently consumed and more familiar to consumers.

The *black cherry, Concord grape, and pomegranate* juice blend was chosen as the best blend to further optimize because 1) it had the highest marginal utility and 2) all three of its blending components are generally reconstituted to higher soluble solids levels than cranberry juice, which made it more suitable than the *Concord grape*, *cranberry, and pomegranate* blend. In the current study, although consumers scored cranberry juice second highest in overall liking, most were probably more familiar with cranberry juice cocktails rather than 100% cranberry juice. Previous consumer research has shown that consumers were previously less accepting of 100% cranberry juice than cranberry juice cocktails (Ghazanfar and Camire 2002). Since sweetness was previously identified as a strong driver of liking, black cherry juice is a more suitable blending component than cranberry juice. Therefore, *black cherry, Concord grape, and pomegranate* was chosen for juice blend optimization

ACKNOWLEDGMENTS

The authors gratefully acknowledge the expertise and guidance provided by Dr. Rodolfo M. Nayga, Jr. and Dr. Faical Akaichi in the completion of this project.

REFERENCES

ANNUNZIATA, A. and VECCHIO, R. 2011. Functional foods development in the European market: A consumer perspective. Journal of Functional Foods *3*, 223-228, DOI: 10.1016/j.jff.2011.03.011.

ARES, G. and GAMBARO, A. 2007. Influence of gender, age and motives underlying food choice on perceived healthiness and willingness to try functional foods. Appetite *49*, 148-158, DOI: 10.1016/j.appet.2007.01.006.

ARES, G., GIMENEZ, A. and GAMBARO, A. 2009. Consumer perceived healthiness and willingness to try functional milk desserts. Influence of ingredient, ingredient name and health claim. Food Qual. Prefer. *20*, 50-56, DOI: 10.1016/j.foodqual.2008.07.002.

ARES, G., GIMENEZ, A. and GAMBARO, A. 2008a. Influence of nutritional knowledge on perceived healthiness and willingness to try functional foods. Appetite *51*, 663-668, DOI: 10.1016/j.appet.2008.05.061.

ARES, G., GIMENEZ, A. and GAMBARO, A. 2008b. Uruguayan consumers' perception of functional foods. J. Sens. Stud. *23*, 614-630.

AYYAGARI, P., GROSSMAN, D. and SLOAN, F. 2011. Education and health: evidence on adults with diabetes. International Journal of Health Care Finance & Economics *11*, 35-54, DOI: 10.1007/s10754-010-9087-x.

BURIN, V.M., FALCAO, L.D., GONZAGA, L.V., FETT, R., ROSIER, J.P. and BORDIGNON-LUIZ, M.T. 2010. Colour, phenolic content and antioxidant activity of grape juice. Ciencia Tecnol. Aliment. *30*, 1027-1032, DOI: 10.1590/S0101-20612010000400030.

CHAPMAN, G.B. 2003. Time Discounting of Health Outcomes. In *Time and Decision: Economic and Psychological Perspectives on Intertemporal Choice*, (G.A. Lowenstein, D. Read and R.F. Baumestier, eds.) pp. 395-418, Russell Sage Foundation, New York, New York.

CHO, M.J., HOWARD, L.R., PRIOR, R.L. and CLARK, J.R. 2004. Flavonoid glycosides and antioxidant capacity of various blackberry, blueberry and red grape genotypes determined by high-performance liquid chromatography/mass spectrometry. J. Sci. Food Agric. *84*, 1771-1782, DOI: 10.1002/jsfa.1885.

DEAN, M., LAMPILA, P., SHEPHERD, R., ARVOLA, A., SABA, A., VASSALLO, M., CLAUPEIN, E., WINKELMANN, M. and LAHTEENMAKI, L. 2012. Perceived relevance and foods with health-related claims. Food Quality and Preference *24*, 129-135.

DEL POZO-INSFRAN, D., PERCIVAL, S.S. and TALCOTT, S.T. 2006. Açaí (Euterpe oleracea mart.) polyphenolics in their glycoside and aglycone forms induce apoptosis of HL-60 leukemia cells. J. Agric. Food Chem. *54*, 1222-1229, DOI: 10.1021/jf052132n.

DOOLEY, L., THRELFALL, R.T. and MEULLENET, J.F. 2012. Optimization of blended wine quality through maximization of consumer liking. Food Qual. and Pref. *24*, 40-47.

DROSSARD, C., FROHLING, B., BOLZENIUS, K., DIETRICH, H., KUNZ, C. and KERSTING, M. 2012. Liking of anthocyanin-rich juices by children and adolescents. Appetite *58*, 623-628.

EL DINE, A.N. and OLABI, A. 2009. Effect of Reference Foods in Repeated Acceptability Tests: Testing Familiar and Novel Foods Using 2 Acceptability Scales. J. Food Sci. *74*, S97-S106, DOI: 10.1111/j.1750-3841.2008.01034.x.

FOLTS, J.D. 1998. Antithrombotic potential of grape juice and red wine for preventing heart attacks. Pharm. Biol. *36*, 21-27.

FRATA, M.T., BENASSI, M.D.T., RODRIGUES MINIM, V.P. and PRUDENCIO, S.H. 2009. Attributes of packing and intention for purchase towards orange juice and nectar. Semin. -Cienc. Agrar. *30*, 847-858.

FREDERICK, S., LOEWENSTEIN, G. and O'DONOGHUE, T. 2002. Time discounting and time preference: A critical review. Journal of Economic Literature *40*, 351-401.

GACULA, M.C. 1993. Design and analysis of sensory optimization.

GHAZANFAR, S. and CAMIRE, M. 2002. Influence of health attitudes on the acceptability of cranberry juice. J. Food Sci. *67*, 3497-3501, DOI: 10.1111/j.1365-2621.2002.tb09612.x.

GOYARZU, F., MALIN, D.H., LAU, F.C., TAGLIALATELA, G., MOON, W.D., JENNINGS, R., MOY, E., MOY, D., LIPPOLD, S., SHUKITT-HALE, B. and JOSEPH, J.A. 2004. Blueberry supplemented diet: Effects on object recognition memory and nuclear factor-kappa B levels in aged rats. Nutr. Neurosci. *7*, 75-83, DOI: 10.1080/10284150410001710410.

GRACIA, A., LOPEZ, B. and VIRUE, S. 2011. Willingness to pay for natural juice: a choice experiment approach. Itea-Informacion Tecnica Economica Agraria *107*, 21-32.

GUO, C., WEI, J., YANG, J., XU, J., PANG, W. and JIANG, Y. 2008. Pomegranate juice is potentially better than apple juice in improving antioxidant function in elderly subjects. Nutr. Res. *28*, 72-77, DOI: 10.1016/j.nutres.2007.12.001.

HAILU, G., BOECKER, A., HENSON, S. and CRANFIELD, J. 2009. Consumer valuation of functional foods and nutraceuticals in Canada. A conjoint study using probiotics. Appetite *52*, 257-265, DOI: 10.1016/j.appet.2008.10.002.

KIM, D.O., HEO, H.J., KIM, Y.J., YANG, H.S. and LEE, C.Y. 2005. Sweet and sour cherry phenolics and their protective effects on neuronal cells. J. Agric. Food Chem. *53*, 9921-9927, DOI: 10.1021/jf0518599.

KRUTULYTE, R., GRUNERT, K.G., SCHOLDERER, J., LAHTEENMAKI, L., HAGEMANN, K.S., ELGAARD, P., NIELSEN, B. and GRAVERHOLT, J.P. 2011. Perceived fit of different combinations of carriers and functional ingredients and its effect on purchase intention. Food Qual. Prefer. *22*, 11-16, DOI: 10.1016/j.foodqual.2010.06.001.

KRYSTALLIS, A., LINARDAKIS, M. and MAMALIS, S. 2010. Usefulness of the Discrete Choice Methodology for Marketing Decision-making in New Product Development: An Example From the European Functional Foods Market. Agribusiness *26*, 100-121, DOI: 10.1002/agr.20236.

LAHTEENMAKI, L., LAMPILA, P., GRUNERT, K., BOZTUG, Y., UELAND, O., ASTROM, A. and MARTINSDOTTIR, E. 2010. Impact of health-related claims on the perception of other product attributes. Food Policy *35*, 230-239, DOI: 10.1016/j.foodpol.2009.12.007.

LANSKY, E.P., HARRISON, G., FROOM, P. and JIANG, W.G. 2005. Pomegranate (Punica granatum) pure chemicals show possible synergistic inhibition of human PC-3 prostate cancer cell invasion across Matrigel (TM). Invest. New Drugs *23*, 121-122.

LAWLESS, L.J.R., NAYGA, R.M., AKAICHI, F., MEULLENET, J.F., THRELFALL, R.T. and HOWARD, L.R. 2012, in press a. Willingness-to-pay for Nutraceutical-rich Juice Blend.

LAWLESS, L.J.R., THRELFALL, R.T., MEULLENET, J.F. and HOWARD, L.R. 2012, in press b. Consumer-Based Optimization of Blackberry, Blueberry, and Concord Juice Blends.

LEE, J., CHAMBERS, E., CHAMBERS, D.H., CHUN, S.S., OUPADISSAKOON, C. and JOHNSON, D.E. 2010. Consumer Acceptance for Green Tea by Consumers in the United States, Korea and Thailand. J. Sens. Stud. *25*, 109-132, DOI: 10.1111/j.1745-459X.2010.00287.x.

MENEZES, E., DELIZA, R., CHAN, H.L. and GUINARD, J. 2011. Preferences and attitudes towards açaí-based products among North American consumers. Food Res. Int. *44*, 1997-2008, DOI: 10.1016/j.goodres.2011.02.048.

O'BYRNE, D.J., DEVARAJ, S., GRUNDY, S.M. and JIALAL, I. 2002. Comparison of the antioxidant effects of Concord grape juice flavonoids and alpha-tocopherol on markers of oxidative stress in healthy adults. Am. J. Clin. Nutr. *76*, 1367-1374.

SABBE, S., VERBEKE, W., DELIZA, R., MATTA, V. and VAN DAMME, P. 2009. Effect of a health claim and personal characteristics on consumer acceptance of fruit juices with different concentrations of açaí (Euterpe oleracea Mart.) RID F-8373-2010. Appetite *53*, 84-92, DOI: 10.1016/j.appet.2009.05.014.

SEERAM, N.P., ADAMS, L.S., ZHANG, Y., LEE, R., SAND, D., SCHEULLER, H.S. and HEBER, D. 2006. Blackberry, black raspberry, blueberry, cranberry, red raspberry, and strawberry extracts inhibit growth and stimulate apoptosis of human cancer cells in vitro. J. Agric. Food Chem. *54*, 9329-9339, DOI: 10.1021/jf061750g.

SEERAM, N.P., AVIRAM, M., ZHANG, Y., HENNING, S.M., FENG, L., DREHER, M. and HEBER, D. 2008. Comparison of antioxidant potency of commonly consumed Polyphenol-Rich beverages in the United States. J. Agric. Food Chem. *56*, 1415-1422, DOI: 10.1021/jf073035s.

SIEGRIST, M., STAMPFLI, N. and KASTENHOLZ, H. 2008. Consumers' willingness to buy functional foods. The influence of carrier, benefit and trust. Appetite *51*, 526-529, DOI: 10.1016/j.appet.2008.04.003.

SLOAN, F.A., PADRON, N.A. and PLATT, A.C. 2009. Preferences, Beliefs, and Self-Management of Diabetes. Health Serv. Res. *44*, 1068-1087, DOI: 10.1111/j.1475-6773.2009.00957.x.

TUORILA, H. and CARDELLO, A.V. 2002. Consumer responses to an off-flavor in juice in the presence of specific health claims. Food Quality and Preference *13*, 561-569.

TUORILA, H., HUOTILAINEN, A., LAHTEENMAKI, L., OLLILA, S., TUOMI-NURMI, S. and URALA, N. 2008. Comparison of affective rating scales and their relationship to variables reflecting food consumption. Food. Qual. Prefer. *19*, 51-61, DOI: 10.1016/j.foodqual.2007.06.007.

VERBEKE, W., SCHOLDERER, J. and LAHTEENMAKI, L. 2009. Consumer appeal of nutrition and health claims in three existing product concepts. Appetite *52*, 684-692, DOI: 10.1016/j.appet.2009.03.007.

VIDIGAL, M.C.T.R., MINIM, V.P.R., CARVALHO, N.B., MILAGRES, M.P. and GONCALVES, A.C.A. 2011. Effect of a health claim on consumer acceptance of exotic Brazilian fruit juices: Acai (Euterpe oleracea Mart.), Camu-camu (Myrciaria dubia), Caja (Spondias lutea L.) and Umbu (Spondias tuberosa Arruda). Food Res. Int. *44*, 1988-1996, DOI: 10.1016/j.foodres.2010.11.028.

FIG. 1. SCREENING SURVEY OUTLINE FOR JUICE BLENDS

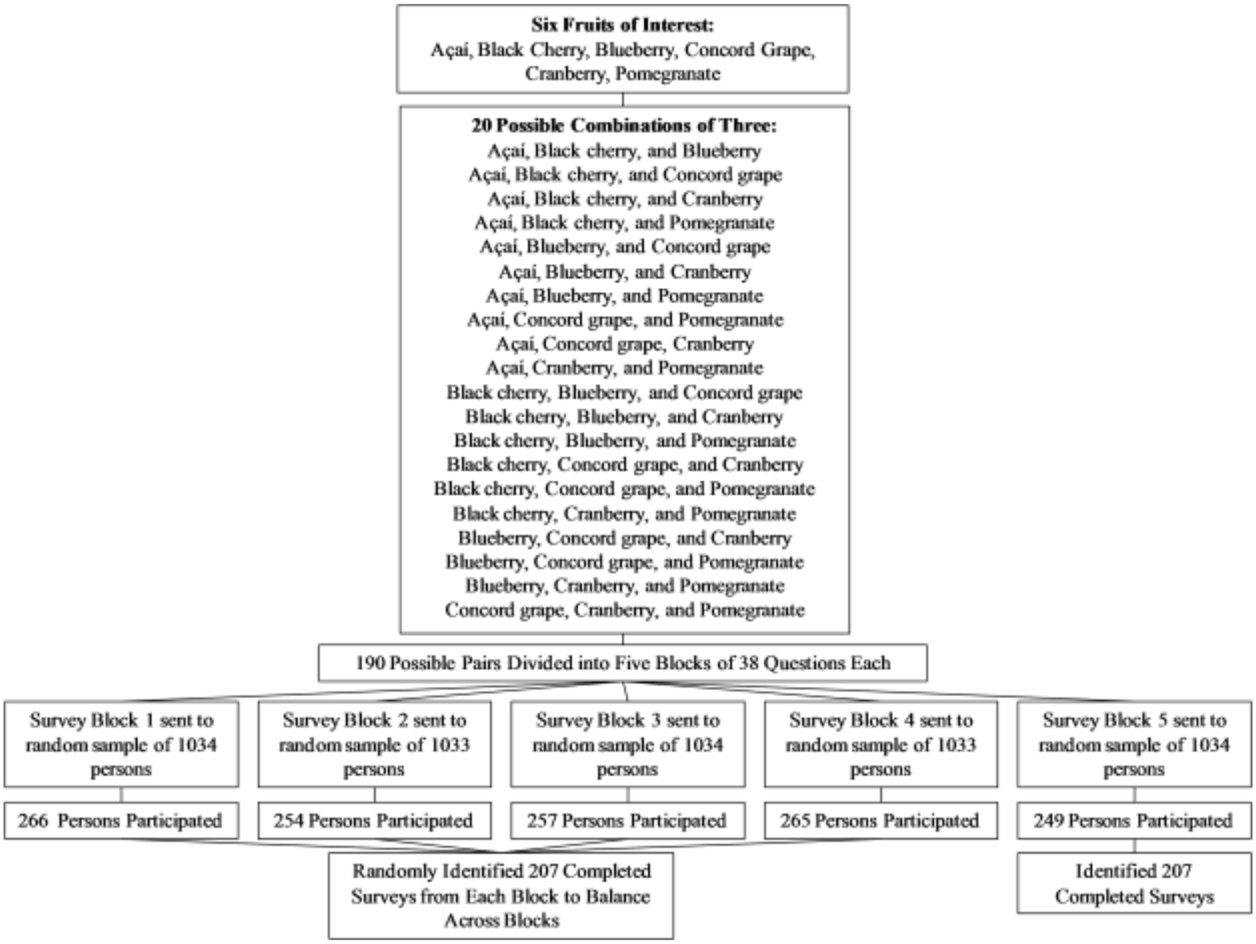


TABLE 1. DEMOGRAPHICS

Gender		
	Male	312
	Female	723
Income		
	$75,000 and Above	224
	$25,000-$74,999	565
	$24,999 and Below	246
Age		
	35 years old and below	436
	36 years old and above	599

TABLE 2. CONSUMPTION FREQUENCY OF JUICES

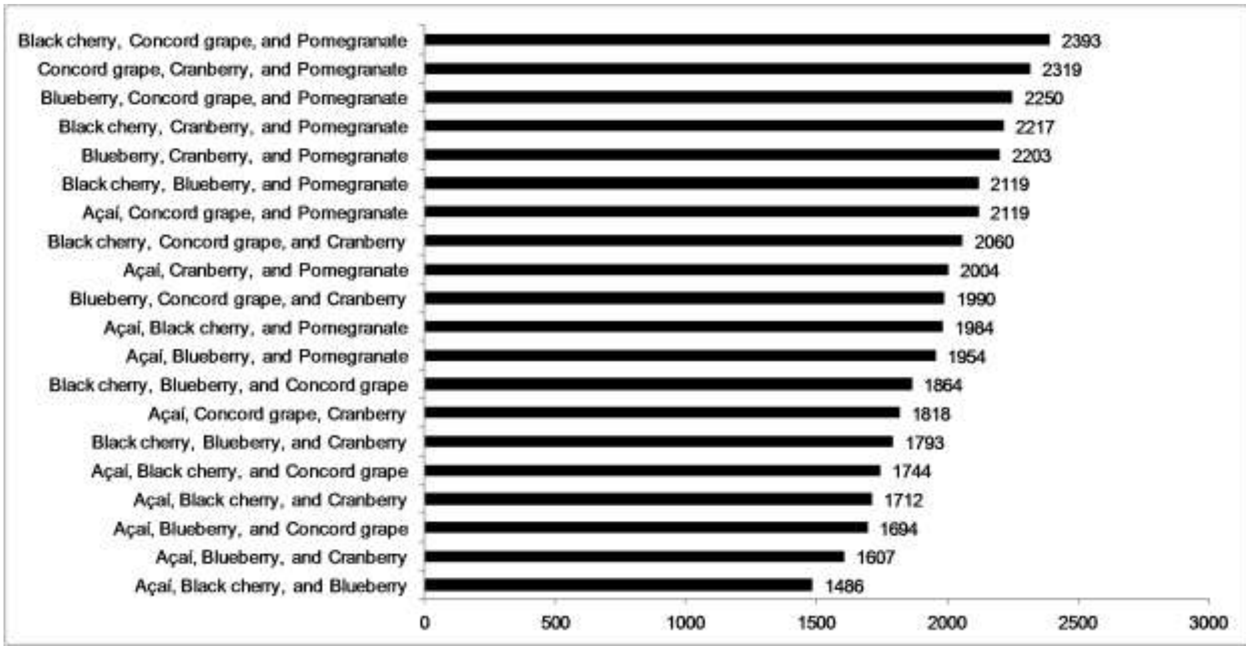
	Açaí Juice	Black Cherry Juice	Blueberry Juice	Concord Grape Juice	Cranberry Juice	Pomegranate Juice
1-7 days ago	200	203	209	418	475	308
8-30 days ago	322	301	304	364	319	353
31-365 days ago	258	325	365	189	187	253
More than 365 days ago	94	144	98	58	48	75
Never	161	62	59	6	6	46

TABLE 3. CONSUMER OVERALL LIKING AND ANTIOXIDANT RANKING[a,b]

Product	Overall Liking	Antioxidant Ranking
Concord	7.81a	2
Cranberry	7.55b	4
Pomegranate	7.39bc	1
Black Cherry	7.15cd	4
Blueberry	7.14d	3
Açaí	6.25e	4

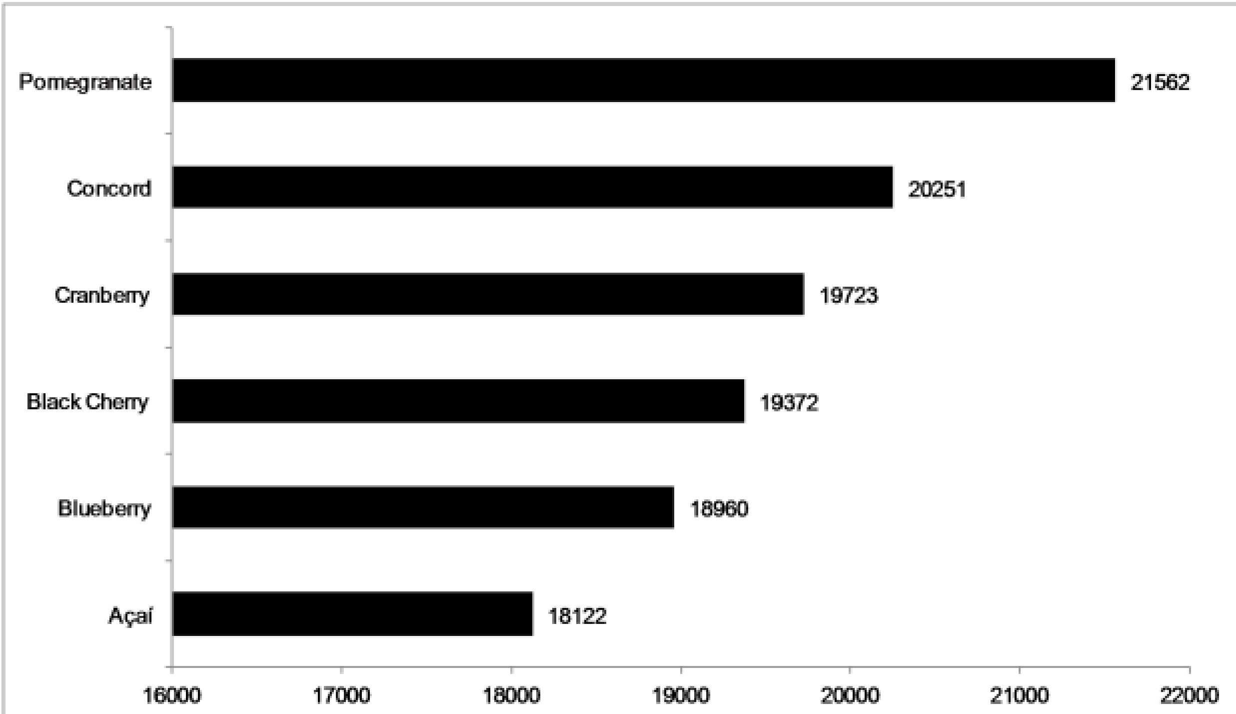
[a]Letters indicate significant differences at $p<0.05$ according to Tukey's HSD test
[b]Antioxidant rankings are based on antioxidant composites developed by Seeram *et al.* 2008

FIG 2. JUICE BLENDS CHOICE FREQUENCIES[a]



[a]Frequencies of juice blends are balanced across 5 blocks (n=1035)

FIG. 3. INDIVIDUAL JUICES CHOICE FREQUENCIES[a]



[a]Frequencies of individual juices are balanced across 5 blocks (n=1035)

TABLE 4. PAIRWISE CORRELATIONS OF ESTIMATED LIKING AND UNFAMILIARITY[a,b,c]

Variable	by Variable	Correlation	P-value
Estimated Average Liking	Açaí	-0.59	<.0001
Estimated Average Liking	Black Cherry	-0.17	<.0001
Estimated Average Liking	Blueberry	-0.19	<.0001
Estimated Average Liking	Concord grape	0.78	<.0001
Estimated Average Liking	Cranberry	0.36	<.0001
Estimated Average Liking	Pomegranate	-0.19	<.0001
Estimated Average Unfamiliarity	Açaí	0.89	<.0001
Estimated Average Unfamiliarity	Black Cherry	0.04	<.0001
Estimated Average Unfamiliarity	Blueberry	0.01	0.0033
Estimated Average Unfamiliarity	Concord grape	-0.44	<.0001
Estimated Average Unfamiliarity	Cranberry	-0.44	<.0001
Estimated Average Unfamiliarity	Pomegranate	-0.08	<.0001
Estimated Average Unfamiliarity	Estimated Average Liking	-0.86	<.0001

[a]Pairwise correlations based on estimated average liking and estimate average unfamiliarity
[b]Equations:
1. (Overall liking (x) + Overall liking (y) + Overall liking (z)/3)= Estimated Average Liking
2. (Frequency Never Consumed (x) + Frequency Never Consumed (y) +Frequency Never Consumed (z)/3)=Estimated Average Unfamiliarity, where
Frequency Never Consumed= Frequency of sampled population who has never consumed a particular component.
[c]Estimated Average Liking and Unfamiliarity are based on balanced sample (n=1035)

TABLE 5. FINAL CHOICE MODEL[a,b]

Term	Estimate	Standard Error
Juice Blend[Açaí, Black cherry, and Blueberry]	1.12	0.27
Juice Blend[Açaí, Black cherry, and Concord grape]	-0.09	0.27
Juice Blend[Açaí, Black cherry, and Cranberry]	0.36	0.27
Juice Blend[Açaí, Black cherry, and Pomegranate]	0.11	0.27
Juice Blend[Açaí, Blueberry, and Concord grape]	0.21	0.25
Juice Blend[Açaí, Blueberry, and Cranberry]	0.66	0.28
Juice Blend[Açaí, Blueberry, and Pomegranate]	-0.47	0.28
Juice Blend[Açaí, Concord grape, and Pomegranate]	-1.48	0.27
Juice Blend[Açaí, Concord grape, Cranberry]	0.37	0.27
Juice Blend[Açaí, Cranberry, and Pomegranate]	-0.77	0.30
Juice Blend[Black cherry, Blueberry, and Concord grape]	0.86	0.28
Juice Blend[Black cherry, Blueberry, and Cranberry]	0.81	0.27
Juice Blend[Black cherry, Blueberry, and Pomegranate]	0.02	0.28
Juice Blend[Black cherry, Concord grape, and Cranberry]	0.48	0.28
Juice Blend[Black cherry, Concord grape, and Pomegranate]	-0.58	0.26
Juice Blend[Black cherry, Cranberry, and Pomegranate]	-0.35	0.27
Juice Blend[Blueberry, Concord grape, and Cranberry]	0.22	0.28
Juice Blend[Blueberry, Concord grape, and Pomegranate]	-0.62	0.27
Juice Blend[Blueberry, Cranberry, and Pomegranate]	0.09	0.29
Pom Liking*Juice Blend[Açaí, Black cherry, and Blueberry]	-0.13	0.02
Pom Liking*Juice Blend[Açaí, Black cherry, and Concord grape]	-0.18	0.02
Pom Liking*Juice Blend[Açaí, Black cherry, and Cranberry]	-0.17	0.02
Pom Liking*Juice Blend[Açaí, Black cherry, and Pomegranate]	0.30	0.02
Pom Liking*Juice Blend[Açaí, Blueberry, and Concord grape]	-0.18	0.02
Pom Liking*Juice Blend[Açaí, Blueberry, and Cranberry]	-0.11	0.02
Pom Liking*Juice Blend[Açaí, Blueberry, and Pomegranate]	0.32	0.03
Pom Liking*Juice Blend[Açaí, Concord grape, and Pomegranate]	0.27	0.02
Pom Liking*Juice Blend[Açaí, Concord grape, Cranberry]	-0.19	0.02
Pom Liking*Juice Blend[Açaí, Cranberry, and Pomegranate]	0.29	0.02
Pom Liking*Juice Blend[Black cherry, Blueberry, and Concord grape]	-0.28	0.02
Pom Liking*Juice Blend[Black cherry, Blueberry, and Cranberry]	-0.24	0.02
Pom Liking*Juice Blend[Black cherry, Blueberry, and Pomegranate]	0.18	0.02
Pom Liking*Juice Blend[Black cherry, Concord grape, and Cranberry]	-0.26	0.02
Pom Liking*Juice Blend[Black cherry, Concord grape, and Pomegranate]	0.09	0.02
Pom Liking*Juice Blend[Black cherry, Cranberry, and Pomegranate]	0.20	0.02
Pom Liking*Juice Blend[Blueberry, Concord grape, and Cranberry]	-0.32	0.02
Pom Liking*Juice Blend[Blueberry, Concord grape, and Pomegranate]	0.09	0.02
Pom Liking*Juice Blend[Blueberry, Cranberry, and Pomegranate]	0.15	0.02
Con Liking*Juice Blend[Açaí, Black cherry, and Blueberry]	-0.27	0.02
Con Liking*Juice Blend[Açaí, Black cherry, and Concord grape]	0.24	0.02
Con Liking*Juice Blend[Açaí, Black cherry, and Cranberry]	-0.22	0.02
Con Liking*Juice Blend[Açaí, Black cherry, and Pomegranate]	-0.25	0.02
Con Liking*Juice Blend[Açaí, Blueberry, and Concord grape]	0.19	0.02
Con Liking*Juice Blend[Açaí, Blueberry, and Cranberry]	-0.30	0.03
Con Liking*Juice Blend[Açaí, Blueberry, and Pomegranate]	-0.27	0.02
Con Liking*Juice Blend[Açaí, Concord grape, and Pomegranate]	0.31	0.02
Con Liking*Juice Blend[Açaí, Concord grape, Cranberry]	0.26	0.02
Con Liking*Juice Blend[Açaí, Cranberry, and Pomegranate]	-0.22	0.02
Con Liking*Juice Blend[Black cherry, Blueberry, and Concord grape]	0.20	0.02
Con Liking*Juice Blend[Black cherry, Blueberry, and Cranberry]	-0.26	0.02
Con Liking*Juice Blend[Black cherry, Blueberry, and Pomegranate]	-0.24	0.02
Con Liking*Juice Blend[Black cherry, Concord grape, and Cranberry]	0.23	0.02
Con Liking*Juice Blend[Black cherry, Concord grape, and Pomegranate]	0.29	0.02

Con Liking*Juice Blend[Black cherry, Cranberry, and Pomegranate]	-0.22	0.02
Con Liking*Juice Blend[Blueberry, Concord grape, and Cranberry]	0.21	0.02
Con Liking*Juice Blend[Blueberry, Concord grape, and Pomegranate]	0.28	0.02
Con Liking*Juice Blend[Blueberry, Cranberry, and Pomegranate]	-0.25	0.03
Blue Liking*Juice Blend[Açaí, Black cherry, and Blueberry]	0.16	0.02
Blue Liking*Juice Blend[Açaí, Black cherry, and Concord grape]	-0.20	0.02
Blue Liking*Juice Blend[Açaí, Black cherry, and Cranberry]	-0.25	0.02
Blue Liking*Juice Blend[Açaí, Black cherry, and Pomegranate]	-0.19	0.02
Blue Liking*Juice Blend[Açaí, Blueberry, and Concord grape]	0.24	0.02
Blue Liking*Juice Blend[Açaí, Blueberry, and Cranberry]	0.27	0.02
Blue Liking*Juice Blend[Açaí, Blueberry, and Pomegranate]	0.29	0.02
Blue Liking*Juice Blend[Açaí, Concord grape, and Pomegranate]	-0.13	0.02
Blue Liking*Juice Blend[Açaí, Concord grape, Cranberry]	-0.22	0.02
Blue Liking*Juice Blend[Açaí, Cranberry, and Pomegranate]	-0.12	0.02
Blue Liking*Juice Blend[Black cherry, Blueberry, and Concord grape]	0.07	0.02
Blue Liking*Juice Blend[Black cherry, Blueberry, and Cranberry]	0.13	0.02
Blue Liking*Juice Blend[Black cherry, Blueberry, and Pomegranate]	0.19	0.02
Blue Liking*Juice Blend[Black cherry, Concord grape, and Cranberry]	-0.29	0.02
Blue Liking*Juice Blend[Black cherry, Concord grape, and Pomegranate]	-0.30	0.02
Blue Liking*Juice Blend[Black cherry, Cranberry, and Pomegranate]	-0.27	0.02
Blue Liking*Juice Blend[Blueberry, Concord grape, and Cranberry]	0.22	0.02
Blue Liking*Juice Blend[Blueberry, Concord grape, and Pomegranate]	0.27	0.02
Blue Liking*Juice Blend[Blueberry, Cranberry, and Pomegranate]	0.28	0.02
Black Cherry Liking*Juice Blend[Açaí, Black cherry, and Blueberry]	0.16	0.02
Black Cherry Liking*Juice Blend[Açaí, Black cherry, and Concord grape]	0.23	0.02
Black Cherry Liking*Juice Blend[Açaí, Black cherry, and Cranberry]	0.24	0.02
Black Cherry Liking*Juice Blend[Açaí, Black cherry, and Pomegranate]	0.23	0.02
Black Cherry Liking*Juice Blend[Açaí, Blueberry, and Concord grape]	-0.23	0.02
Black Cherry Liking*Juice Blend[Açaí, Blueberry, and Cranberry]	-0.23	0.02
Black Cherry Liking*Juice Blend[Açaí, Blueberry, and Pomegranate]	-0.20	0.02
Black Cherry Liking*Juice Blend[Açaí, Concord grape, and Pomegranate]	-0.20	0.02
Black Cherry Liking*Juice Blend[Açaí, Concord grape, Cranberry]	-0.24	0.02
Black Cherry Liking*Juice Blend[Açaí, Cranberry, and Pomegranate]	-0.25	0.02
Black Cherry Liking*Juice Blend[Black cherry, Blueberry, and Concord grape]	0.22	0.02
Black Cherry Liking*Juice Blend[Black cherry, Blueberry, and Cranberry]	0.21	0.02
Black Cherry Liking*Juice Blend[Black cherry, Blueberry, and Pomegranate]	0.22	0.02
Black Cherry Liking*Juice Blend[Black cherry, Concord grape, and Cranberry]	0.21	0.02
Black Cherry Liking*Juice Blend[Black cherry, Concord grape, and Pomegranate]	0.30	0.02
Black Cherry Liking*Juice Blend[Black cherry, Cranberry, and Pomegranate]	0.28	0.02
Black Cherry Liking*Juice Blend[Blueberry, Concord grape, and Cranberry]	-0.24	0.02
Black Cherry Liking*Juice Blend[Blueberry, Concord grape, and Pomegranate]	-0.25	0.02
Black Cherry Liking*Juice Blend[Blueberry, Cranberry, and Pomegranate]	-0.24	0.02
Açaí Liking*Juice Blend[Açaí, Black cherry, and Blueberry]	0.11	0.02
Açaí Liking*Juice Blend[Açaí, Black cherry, and Concord grape]	0.07	0.01
Açaí Liking*Juice Blend[Açaí, Black cherry, and Cranberry]	0.15	0.02
Açaí Liking*Juice Blend[Açaí, Black cherry, and Pomegranate]	0.09	0.01
Açaí Liking*Juice Blend[Açaí, Blueberry, and Concord grape]	0.15	0.02
Açaí Liking*Juice Blend[Açaí, Blueberry, and Cranberry]	0.06	0.01
Açaí Liking*Juice Blend[Açaí, Blueberry, and Pomegranate]	0.12	0.01
Açaí Liking*Juice Blend[Açaí, Concord grape, and Pomegranate]	0.09	0.01
Açaí Liking*Juice Blend[Açaí, Concord grape, Cranberry]	0.09	0.01
Açaí Liking*Juice Blend[Açaí, Cranberry, and Pomegranate]	0.12	0.01
Açaí Liking*Juice Blend[Black cherry, Blueberry, and Concord grape]	-0.06	0.01
Açaí Liking*Juice Blend[Black cherry, Blueberry, and Cranberry]	-0.08	0.01
Açaí Liking*Juice Blend[Black cherry, Blueberry, and Pomegranate]	-0.08	0.01
Açaí Liking*Juice Blend[Black cherry, Concord grape, and Cranberry]	-0.10	0.01

Açaí Liking*Juice Blend[Black cherry, Concord grape, and Pomegranate]	-0.08	0.01
Açaí Liking*Juice Blend[Black cherry, Cranberry, and Pomegranate]	-0.13	0.01
Açaí Liking*Juice Blend[Blueberry, Concord grape, and Cranberry]	-0.13	0.01
Açaí Liking*Juice Blend[Blueberry, Concord grape, and Pomegranate]	-0.09	0.01
Açaí Liking*Juice Blend[Blueberry, Cranberry, and Pomegranate]	-0.14	0.01
Cranberry Liking*Juice Blend[Açaí, Black cherry, and Blueberry]	-0.22	0.02
Cranberry Liking*Juice Blend[Açaí, Black cherry, and Concord grape]	-0.19	0.02
Cranberry Liking*Juice Blend[Açaí, Black cherry, and Cranberry]	0.18	0.02
Cranberry Liking*Juice Blend[Açaí, Black cherry, and Pomegranate]	-0.16	0.02
Cranberry Liking*Juice Blend[Açaí, Blueberry, and Concord grape]	-0.22	0.02
Cranberry Liking*Juice Blend[Açaí, Blueberry, and Cranberry]	0.19	0.02
Cranberry Liking*Juice Blend[Açaí, Blueberry, and Pomegranate]	-0.16	0.02
Cranberry Liking*Juice Blend[Açaí, Concord grape, and Pomegranate]	-0.12	0.02
Cranberry Liking*Juice Blend[Açaí, Concord grape, Cranberry]	0.20	0.02
Cranberry Liking*Juice Blend[Açaí, Cranberry, and Pomegranate]	0.30	0.02
Cranberry Liking*Juice Blend[Black cherry, Blueberry, and Concord grape]	-0.28	0.02
Cranberry Liking*Juice Blend[Black cherry, Blueberry, and Cranberry]	0.11	0.02
Cranberry Liking*Juice Blend[Black cherry, Blueberry, and Pomegranate]	-0.24	0.02
Cranberry Liking*Juice Blend[Black cherry, Concord grape, and Cranberry]	0.13	0.02
Cranberry Liking*Juice Blend[Black cherry, Concord grape, and Pomegranate]	-0.18	0.02
Cranberry Liking*Juice Blend[Black cherry, Cranberry, and Pomegranate]	0.21	0.02
Cranberry Liking*Juice Blend[Blueberry, Concord grape, and Cranberry]	0.20	0.02
Cranberry Liking*Juice Blend[Blueberry, Concord grape, and Pomegranate]	-0.20	0.02
Cranberry Liking*Juice Blend[Blueberry, Cranberry, and Pomegranate]	0.22	0.02

[a]Estimates indicate contribution to utility of each effect

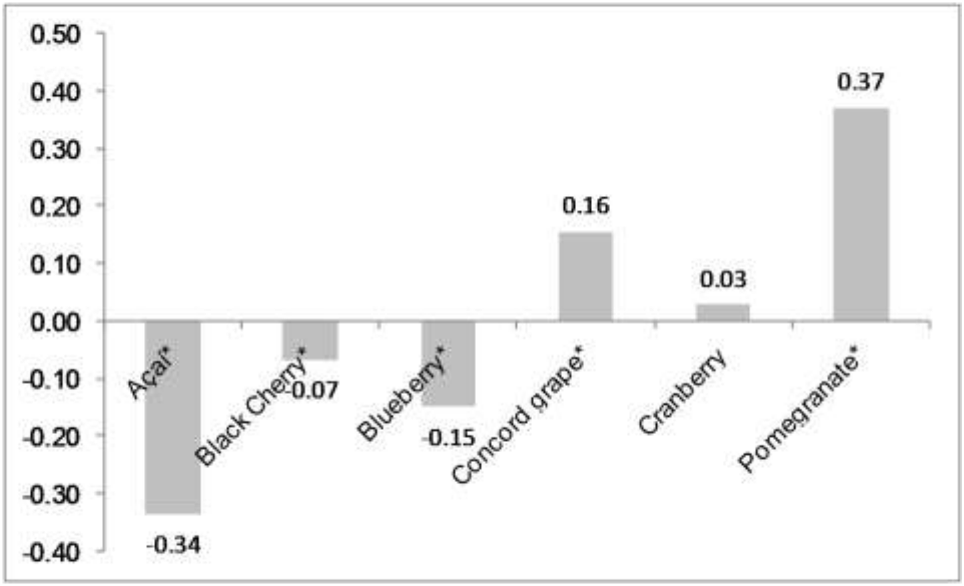
[b]Abbreviations: Pomegranate overall Liking (Pom Liking), Concord grape overall liking (Con Liking), Blueberry overall liking (Blue Liking), Black cherry overall liking (Black Cherry Liking), Açaí overall liking (Açaí Liking), Cranberry overall liking (Cranberry Liking)

TABLE 6. MARGINAL UTILITIES OF JUICE BLENDS DETERMINED BY CONSUMER CHOICES[a]

Juice Blend	Utility	Cluster
Black cherry, Concord grape, and Pomegranate	0.51	1
Concord grape, Cranberry, and Pomegranate	0.49	1
Blueberry, Concord grape, and Pomegranate	0.35	2
Black cherry, Cranberry, and Pomegranate	0.31	2
Blueberry, Cranberry, and Pomegranate	0.29	2
Açaí, Concord grape, and Pomegranate	0.19	2
Black cherry, Concord grape, and Cranberry	0.17	2
Black cherry, Blueberry, and Pomegranate	0.15	2
Blueberry, Concord grape, and Cranberry	0.07	3
Açaí, Cranberry, and Pomegranate	0.01	3
Açaí, Black cherry, and Pomegranate	0.01	3
Açaí, Blueberry, and Pomegranate	-0.08	3
Black cherry, Blueberry, and Concord grape	-0.10	3
Açaí, Concord grape, Cranberry	-0.15	3
Black cherry, Blueberry, and Cranberry	-0.22	4
Açaí, Black cherry, and Concord grape	-0.27	4
Açaí, Blueberry, and Concord grape	-0.33	4
Açaí, Black cherry, and Cranberry	-0.37	4
Açaí, Blueberry, and Cranberry	-0.43	4
Açaí, Black cherry, and Blueberry	-0.59	4

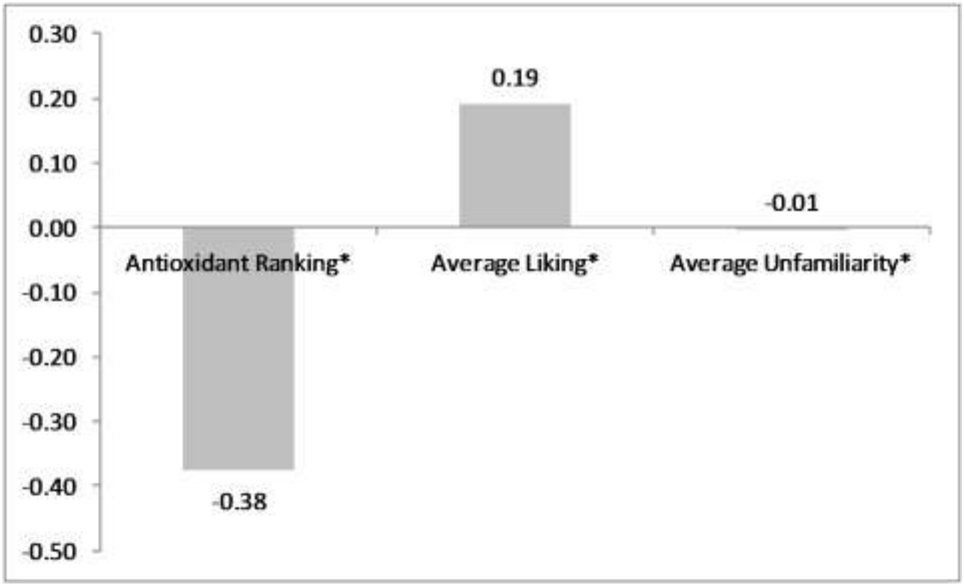
[a]Clusters are determined by hierchical cluster analysis on marginal utilities in order to distinguish among groups with similar marginal utilities

FIG. 4. PARTIAL LEAST SQUARES REGRESSION ON MARGINAL UTILITY[a,b]



[a]Partial least squares regression unweighted beta coefficients with marginal utility as response and blending component binary variables as predictors
[b]* Indicates significance at $p<0.01$

FIG. 5. PARTIAL LEAST SQUARES REGRESSION ON MARGINAL UTILITY[a,b,c]



[a]Partial least squares regression unweighted beta coefficients with marginal utility as response and average antioxidant ranking, estimated average liking, and estimated average unfamiliarity as predictors

[b]*Indicates significance at $p<0.01$

[c]Equations:

1. (Overall liking (x) + Overall liking (y) + Overall liking (z)/3)= Estimated Average Liking
2. (Frequency Never Consumed (x) + Frequency Never Consumed (y) +Frequency Never Consumed (z)/3)=Estimated Average Unfamiliarity, where
Frequency Never Consumed= Frequency of sampled population who has never consumed a particular component.
3. (Antioxidant ranking (x) + Antioxidant ranking (y) + Antioxidant ranking (z)/3)=Average Antioxidant Ranking

CHAPTER 7

Applying a Mixture Design to Consumer Optimization of Black Cherry,

Concord Grape, and Pomegranate Juice Blends

Lydia J. R. Lawless, Renee T. Threlfall, Jean-François Meullenet, Luke R. Howard

Formatted for submission to the Journal of Sensory Studies

ABSTRACT

Expanding interest in the nutraceutical market inspires sensory- and nutraceutical-oriented optimization methods. Black cherry (BlkCh), Concord grape (Con), and pomegranate (Pom) juices were blended according to a mixture design (7 blending treatments). Consumers (n=100) evaluated estimated overall liking (OL) before tasting, OL pre- and post-antioxidant-information, purchase intent, just-about-right (JAR) attributes, and familiarity to determine an optimum formulation and the influence of consumer characteristics on acceptance of potentially nutraceutical-rich juices. Post-antioxidant-information OL means were high for Con juice (7.48), low for BlkCh juice (5.01), and low for Pom juice (5.01). The desirability function generated solutions based on OL for pre-antioxidant-information (77%Con+3%Pom+20%BlkCh) and post-antioxidant-information (75%Con+12%Pom+13%BlkCh). The post-antioxidant-information solution had a higher level of Pom, as Pom juice was reported to have the most antioxidants. Descriptive (n=10) and consumer (n=100) data showed that Con juice and its attributes (sweetness, Concord flavor, caramelized flavor) were positive and that the attributes of BlkCh and Pom juices were negative. JAR variable analysis showed that 33%Con+33%Pom+33%BlkCh blend had fewer non-optimal attributes than 100%Pom or 100%BlkCh and had more antioxidants than 100%Con.

PRACTICAL APPLICATIONS

Black cherry, Concord grape, and pomegranate juice blends are prime candidates for the nutraceutical juice market because of their inherent health-oriented characteristics and portable convenience. Consumer-driven approaches to balance the nutraceutical and sensory quality of products are necessary to optimize consumer utility. Merely applying instrumental measures of nutraceutical levels (e.g. total phenolics, total anthocyanins) to optimization models does not incorporate how consumers value those attributes; thus, an optimization that applied consumer

value of antioxidants was used, the principle of which could aid in the future development of nutraceutical beverages.

KEYWORDS: optimization, juice, preference map, nutraceutical, functional food, desirability

INTRODUCTION

An aging population and the prevalence of obesity are catalysts to the growing interest in healthy foods and the nutraceutical market (Stephens 2008, Mokdad *et al.* 2004). Nutraceutical-rich juices (i.e., juices with potential benefits beyond basic nutrition) may be especially successful in the marketplace because of their combined sensory appeal, convenience, and perceived natural healthfulness (Gracia *et al.* 2011, Annunziata and Vecchio 2011, Siegrist *et al.* 2008, Carrillo *et al.* 2011).

Seeram *et al.* (2008) reported antioxidant levels of juices and identified dark fruit juices such as black cherry, Concord grape, pomegranate, blueberry, açaí, and cranberry as being especially antioxidant-rich. Juice blending was used previously to achieve more desirable levels of nutraceuticals while maintaining or improving sensory acceptance by consumers (unpublished observations). Typically, three or four mixture components are suitable for sensory mixture optimization (Gacula 1993), and mixture designs have been applied to optimizations of three-component wine and juice blends (Dooley *et al*. 2012; Koak *et al.* 2010; Lawless *et al.* 2012 in press). Identification of the optimum proportions in juice and wine mixtures has been accomplished with the desirability function (unpublished observations, Dooley *et al.* 2012). In the software package, JMP (Cary, NC), the overall desirability function summarizes the solutions for all responses through determining the geometric mean of each response's desirability. The elicited solution balances each consumer's overall liking.

Several statistical methods are helpful to the product optimization process because they identify the desirable and undesirable attributes in a product set. External preference mapping overlays consumers on a principal component analysis two-dimensional plot based on the product by attribute matrix, which generalizes the products and attributes positively and negatively associated with consumer acceptance (Meullenet *et al.* 2007). Partial least squares regression can be used to identify the relationships between attributes and overall liking. Attributes can be assessed with a trained, descriptive panel or with consumer-generated information such as just-about-right (JAR) diagnostic data. Directly relating JAR attributes to hedonic scores collected with the nine-point verbal hedonic scale was once problematic because the scales are not similarly balanced. The ideal score on the JAR scale is 3 (just-about-right) out of 5, and the ideal score on the nine-pint verbal hedonic scale is 9 (like extremely) out of 9. To overcome this challenge, Xiong and Meullenet (2006) proposed converting a single JAR attribute into two dummy variables, one which represents the *too little* side of the JAR scale and one that represents the *too much* side. Preference mapping and partial least squares regression on JAR data can aid in the optimization process through providing diagnostic information about products.

Conceivably, some consumers gain utility from the health aspects of products as well as the sensory quality (Carrillo *et al.* 2011, Ares *et al.* 2008, Ares *et al.* 2010a). Juices from dark-pigmented fruits such as pomegranate, Concord grape and black cherry have been shown to have high levels of nutraceutical compounds (Seeram *et al.* 2008). Pomegranates are rich sources of ellagitannins and their associated derivatives, which have been shown to potentially have antioxidant, anti-inflammatory, and anti-cancer effects (particularly for prostate cancer) (Faria and Calhau 2011, Ishimoto *et al.* 2011, Mena *et al.* 2011). Concord grapes have been associated with pro-immunity, antioxidant, anticancer, and neurological protective effects (Rowe *et al.* 2011, Burin *et al.* 2010, Krikorian *et al.* 2010, Singletary *et al.* 2007). Similarly, cherries are sources of anthocyanins, which are also associated with antioxidant, anticancer, and neurologically protective effects (Kelebek and Selli. 2011, Ranceliene *et al.* 2009, Folts 1998, Seeram *et al.* 2006, Joseph *et al.* 1999, Joseph *et al.* 1998). The expectations that consumers have for nutraceuticals may depend on the characteristics of differing consumer segments (Ares et al. 2010b,Verbeke 2005).

Hence, the objectives of this research were to 1) determine the optimum proportions of black cherry, Concord grape, and pomegranate juice in a juice blend and 2) describe how nutraceutical status, consumer characteristics, and sensory attributes influence consumer overall liking and purchase intent of nutraceutical-rich juice blends. The screening experiment that occurred previous to this optimization and identified black cherry, pomegranate, and Concord grape juice as desirable blending components was presented in a companion paper entitled *Using a Choice Design to Screen Nutraceutical-Rich Juices*.

MATERIALS AND METHODS

Sesnory Panels

Consumer and descriptive evaluations were completed at the Sensory and Consumer Research Center, University of Arkansas, Fayetteville.

Consumer Panel. Consumers (n=100) were recruited based on frequency of juice consumption (3 times per week) and liking of black cherries, pomegranates, and Concord grapes. Panelists received a monetary incentive for their participation. The demographics of the consumers were gender (n=27 men, n= 73 women), income (n=18 $80,000 and above; n=51 $30,000 to $79,999; and n=31 $29,999 and below) and age (n=36 35-years-old and above, n=64 36-years-old and above). The majority of participants were female, over the age of 35, and made more than $30,000 annually. Of the three juices tested in this study, more consumers had more recently purchased Concord juice than had purchased pomegranate, and/or black cherry juice (Table 1).

Descriptive Panel. Each descriptive panelist had at least 7 years of experience evaluating various food products six hours per week. Descriptive panelists (n=10) participated in a two-hour orientation and practice session. The ballot was developed through consenus using previously published lexicons as guides (Koppel and Chambers 2010, Boiago Golluecke *et al.* 2008). Panelists evaluated all seven juice samples in duplicate using the Spectrum® method.

Juice Products

In previous work, consumers (n=1291) were administered a choice survey to determine the best three-component juice blend. The black cherry, Concord grape, and pomegranate juice had the highest marginal utility (x=0.51) and thus was chosen for optimization in this project. Commercial black cherry (Kerr Concentrates, Inc., Salem, OR, 68% soluble solids), Concord grape (FruitSmart, Grandview, WA, 66.5% soluble solids), and pomegranate (Kerr Concentrates, Inc., Salem, OR, 63.7% soluble solids) juice concentrates were reconstituted to 16.5% soluble solids. All juice concentrates were standardized to the same soluble solids to reduce the sweetness bias. Each consumer evaluated the seven blending treatments created from using the simplex centroid mixture design (Figure 1) without replications. Juice was bottled, pasteurized, sealed, and stored at 2°C until use.

Experimental Design

Central Location Test. Presentation order was balanced across panelists to control order effects during evaluation. Samples were served sequential monadically and were assigned random 3-digit blinding codes.

The consumer ballot addressed estimated liking for a black cherry, Concord, and pomegranate juice blend, overall liking, JAR attributes, purchase intent, familiarity with the produts, and demographics. Overall liking based on the nine-point verbal hedonic score was measured for each juice treatment before (pre-information) and after (post-information) consumers were given information about the antioxidant composite score of each sample. Antioxidant composites were estimated based on previous research (Seeram *et al.* 2008) rather than determined solely on the current samples to create antioxidant composites more representative of commercially available juices. In addition to the antioxidant composite, consumers were given the ranking (1-7) of each sample's composite compared to all other samples they tasted during the evaluation. Seeram *et al.* (2008) originally developed the composites for black cherry, Concord grape, and pomegranate juices by performing multiple antioxidant capacity assays on various juice brands. For the current study, antioxidant composites for the blends were based on the average of the single components (Table 2).

The price of each sample was estimated based on the bulk price of the juice concentrates and volume of juice. Consumers were given the estimated price when asked about purchase intent for a particular sample. Consumers rated purchase intent on a five-point scale from "Definitely would buy" (5) to "Definitely would not buy" (1).

Familiarity for black cherry, Concord grape, and pomegranate juice and juice blends was measured with the question, "How many times have you consumed *juice x*?", and responses, "Maybe never, Once or Twice, Three to Five Times, Six to Twenty Times, and More times than I can count." Consumer responses were collected via Compusense (Compusense *five*, release 4.8, Compusense Inc., Guelph, Ontario, Canada).

Descriptive Analysis. Presentation order was randomized for each panelist to aid in controlling order effects. Products were identified with random three digit numbers.

The attributes in the final lexicon were sweet, sour, bitter, Concord grape note, black cherry note, other berry note, unripe fruit, overripe fruit, beet, cranberry, prune, musty earthy, skin/seeds, oxidized, caramelized, carrot, sour cherry, fermented, metallic flavor, metallic (feeling factor), astringency, toothetch, throat burn, and prickle bite.

Total Phenolics. The Folin-Ciocalteu assay was used to measure total phenolics (Slinkard and Singleton 1977). The gallic acid standard was built on serial dilutions (final concentrations 12.5, 25, 50, 100, 200 µg/mL). Asorbancies were measured at 760nm and units used were gallic acid equivalents (GAE). Total phenolics in 100%BlkCh, 100%Con, 100%Pom match the order of the antioxidant composites (Table 2).

Statistical Analysis

For the consumer study, two-way ANOVA with panelist as a random effect and product as a fixed effect was performed on pre- and post- information overall liking means and purchase intent (JMP 9.0.2, Cary, NC). Preliminary analysis included hierarchical cluster analysis by Ward's criterion on centered data, which did not produce segmentation (Unscrambler X 10.1, Camo, Woodbridge Township, New Jersey). The desirability function was used to determine the optimum juice blend (JMP 9.0.2, Cary, NC). Pearson's and pairwise correlations were performed on overall liking, purchase intent, price, and antioxidant composite (JMP 9.0.2, Cary, NC). Three-way ANOVA with panelist as a random effect, product as a fixed effect, and the panelist*product interaction effect was performed on descriptive data. All attributes were significant. Principal component analysis (PCA) was performed on the attribute and product correlation matrix (JMP 9.0.2, Cary, NC). Consumers were fitted to the first two principal components model with Pearson's correlations. JAR attributes were converted to continuous variables. For conversion to the *too much* dummy, observations scored at 5 and 4 are converted to 2 and 1 respectively, and all other observations are converted to 0s. The 2s and 1s on the *too little* side of the JAR attribute are converted to -1 and -2 respectively in the *too little* dummy. A pair of dummies was developed for each JAR attribute, and partial least squares regression with overall liking as the response was performed. Converted JAR variables were mean centered and standardized before regression (Unscrambler X 10.1, Camo, Woodbridge Township, New Jersey).

RESULTS AND DISCUSSION

Consumer Acceptance

Desirability. The desirability function represents a globalized view of multiple response variables. In this application, for each consumer, the blend that maximizes a particular consumer's overall hedonic score was identified and assigned a desirability. The overall desirability function represents the geometric mean of all desirabilities for all consumers.

Before consumers were given antioxidant information, the most desirable blend (desirability= 0.81) based on overall liking scores was 77%Con+3%Pom+20%BlkCh. After consumers were given antioxidant information, the most desirable blend (desirability=0.71) was 75%Con+12%Pom+13%BlkCh. The shift in desirability toward a blend with more pomegranate juice and less black cherry juice was consistent with the pattern of the antioxidant information. Pomegranate was highest in antioxidants while black cherry was the lowest in antioxidants.

The desirable pre- and post- information regions are represented by the lightly shaded areas in the ternary plots (Figures 2 and 3). Presumably, the region which represents the blends with the highest hedonic rating is not limited to one point, which is supported by mean seperation on overall liking (Table 3). For example, consumers liked 100% Con juice as much as blends that only contained 50% Con juice. For pre- and post- information ternary plots, blends with the same reported desirability increased as significant digits decreased.

Previously, when a blackberry, blueberry, and Concord juice blend was optimized with the desirability function, the resulting solution was predominantly Concord juice (unpublished observations). In that study, the strong acceptance of Concord juice was attributed to its higher sweetness level. The standardization of soluble solids in the current study decreased the sweetness bias; however, pomegrante juice was more sour than the other juices, which could have interfered with sweetness perception (Shallenberger 1993). Dooley *et al.* (2012) optimized a wine blend with smaller differences within the blending components (three grape varietals compared to three separate fruits) and produced a global solution more inclusive to all three blending components. However, when consumers were examined by segment, the optimized solution was strongly driven by one blending component. Similary, in our study, consumers had similar preferences strongly driven by Concord grape juice.

Estimated and Overall Liking. Concord juice and Concord juice blends were the most desirable treatments among consumers before and after consumers were given information about antioxidant levels (Table 3). Concord juice was second highest in antioxidants and its flavor profile is highly familiar to consumers, which could have contributed to its higher liking scores. Antioxidant information positively influenced the overall liking scores for pomegranate juice and pomegranate blends, most likely because pomegranate was highest in antioxidants. Liking scores for 100% BlkCh juice were low pre- and post- information, probably because 100% BlkCh juice was lowest in antioxidants and was least frequently consumed by consumers (Table 1).

Consumers were asked to evaluate their estimated liking for a black cherry, Concord grape, and pomegranate juice blend. Estimated liking (mean=8.09) was compared to pre-and post-information overall liking for all products. According to t-test analysis, overall liking for pre- and post-information was lower than expected liking for the blend. However, significant changes between pre- and post-information were shown. Shifts upward were seen for blends that were at least 50% pomegranate, which had the highest antioxidant composite. Similarly, Sabbe *et al.* 2009) found that overall liking scores increased for açaí juices when health information was given, and the increase was higher for the juice with the higher concentration of açaí. Vidigal *et al.* (2011) found a similar positive effect of health information on acceptance of cajá, acai, camu-camu, and umbu juices. However, similar to pomegranate juice in the current study, the hedonic score for camu-camu juice increased when health information was presented, but the final hedonic score indicated that the juice was unsuccessful in terms overall liking. Nutraceutical information can increase consumer acceptance, but it cannot readily compensate for undesirable sensory profiles (Bech-Larsen and Scholderer 2007).

Purchase Intent. Correlations showed that purchase intent was significantly related to overall liking pre-information (r=0.99) and overall liking post-information information (r=0.99), but not to price or antioxidant composite, which supports previous research in which consumers valued sensory properties more than health properties (Sabbe *et al.* 2009) (Table 4). Similarly, purchase intent for a healthy ready-to-heat meal was primarily dependent on overall liking of the meal (Olsen *et al.* 2012). High personal involvement or relevance with the product was shown to increase purchase intent for other antioxidant-rich products and increase interest in functional foods (Ares *et al.* 2010c, Dean *et al.* 2012). Purchase intent may have been higher for products that were predominantly Concord juice because most consumers have more recently consumed Concord juice than pomegranate or black cherry juice and thus had higher personal relevance to that product (Table 1).

Familiarity. In order to determine the influence of familiarity of a juice on the hedonic scores for particular samples, contingency analysis was performed. Responses to the nine-point verbal hedonic score were recorded as “Like” for scores 6-9, “Neutral” for score 5, and “Dislike” for scores 1-4. Familiarity was recoded as “Familiar” for individuals who had prior exposure to a particular juice and “Not Familiar” for individuals who had never been exposed to a particular juice. For models with sufficient sample sizes in each cell, familiarity was not shown to affect liking, which is not demonstrated by previous literature that showed familiarity affected consumer acceptance in nutraceutical beverages (e.g., green tea, calcium fortified drink) (Lee *et al.* 2010, Tuorila *et al.* 2008). Discrepancies between this study and previuos work could have been due to a less diverse sample, smaller sample size, or different measures of familiarity (Lee *et al.* 2010, Tuorila *et al.* 2008).

Drivers of Consumer Acceptance

External Preference Mapping. According to external preference mapping, Concord and Concord juice blends are characterized by sweetness, caramelization, and Concord flavor (Figure 4). The hedonic vectors of most consumers were highly correlated to the attribute vectors associated with Concord juice, which indicates that Concord juice possessed positive characteristics. Previous studies have identified sweetness as an important factor in overall liking of juice as well as other nutraceutical products (Drossard *et al.* 2012, Chung *et al.* 2011).

The attributes associated with black cherry juice (black cherry, prune, overripe fruit, and oxidized) and pomegranate juice (beet, carrot, musty earthy, fermented, sour cherry, other berry, bitter, throat burn, cranberry, prickle bite, toothetch, sour, astringency, skin/seeds, metallic flavor, metallic (feeling factor), and unripe fruit) were not associated with the hedonic vectors of many consumers, which indicates that these products and attributes were more negatively perceived. Astringency and bitterness were identified as non-drivers of overall liking in other products (Bayarri *et al.* 2012, Leksrisompong *et al.* 2012).

Just-About-Right Attributes. As in previous work, JAR data was used to identify non-optimal fruit juice attributes (Threlfall *et al.* 2007). To determine the effect of blending on developing juice blends with optimal attributes, results are shown for primary treatments (BlkCh, Con, Pom) and the balanced blend (33%BlkCh+33%Con+33%Pom). Significant coefficients indicated possible adjustments to attributes that could be made to each product. For most variable sets, either the *too much* or the *too little* side of the JAR attribute was significant and had a higher coefficient than the other, which suggested a direction to improve the product (Table 5). 100%BlkCh juice did not have enough sweetness, sourness, pomegranate flavor, Concord grape flavor, and astringency and had too much black cherry flavor and bitterness. 100%Con juice had too much sourness and astringency. 100%Pom juice did not have enough sweetness or Concord flavor and had too much sourness, pomegranate flavor, astringency, and bitterness.

Coefficients indicated the effect of the attribute on mean overall liking. For example, 100% Pom juice had 6 attributes that were not JAR. The 0.01 coefficient for *too sweet* indicated that this side of the attribute had little effect on overall liking; however, the 0.64 coefficient for *not sweet enough* indicated that overall liking increased at a rate of 0.64 per unit of sweetness over the region of 1 to 3 (too little region). The opposite pattern was observed for sourness. Mean overall liking decreased at a rate of 0.67 per unit of sourness over the region of 3 to 5 (too much region). The 0.06 coefficient of *not sour enough* indicated little to no effect on overall liking. For the remaining significant attributes of 100%Pom juice, overall liking decreased 0.37 per unit of pomegranate flavor, 0.38 per unit of astringency, and 0.70 per unit of bitterness over the region of 3 to 5 (too much region). Overall liking increased 0.23 per unit of Concord flavor over the region of 1 to 3 (too little region). The counterpart of these attributes had coefficients near 0, which indicated they were not as important to overall liking. The intercept for 100%Pom was 7.64, which would be the potential maximum overall liking score if all of the variables were JAR. Similar patterns were observed for the other products with variables not JAR. The magnitude and significance of the coefficients provide direction for each product's improvement.

The 33%BlkCh+33%Con+33%Pom juice blend had 4 unbalanced attributes (UAs), which was less than 100%Pom juice (6 UAs) or 100%BlkCh juice (7 UAs) but was more than 100%Con juice (2 UAs). The increased percentage of pomegranate juice in the 33%BlkCh+33%Con+33%Pom juice blend produced a juice product with a higher antioxidant capacity than 100%Con or 100% BlkCh juices. Blending produced a better-balanced juice than 100%Pom or 100%BlkCh juices, which supports the development of optimization procedures based on sensory and nutraceutical characteristics.

CONCLUSIONS

Consumer acceptance was driven primarily by sensory qualities, although nutraceutical status provided consumers additional utility. The advantage of evaluating consumer acceptance and purchase intent after consumers have information about the nutraceutical status and sensory properties of the product is that the ensuing optimization considers the value of the nutraceutical information as measured by consumers, not laboratory instruments. Understanding the influence of familiarity on consumer acceptance is especially important because the unfamiliar sensory attributes of some nutraceuticals may interfere with consumer satisfaction. Evaluating consumer acceptance data for nutraceuticals in conjunction with descriptive and diagnostic (e.g., JAR) data provided a more comprehensive understanding of how products should be adjusted to maximize consumer acceptance.

ACKNOWLEDGMENTS

The authors would like to thank Dr. Rudy M. Nayga, Jr. and Tonya S.P. Tokar for their expertise and assistance during the execution of this project.

REFERENCES

ANNUNZIATA, A. and VECCHIO, R. 2011. Functional foods development in the European market: A consumer perspective. Journal of Functional Foods *3*, 223-228, DOI: 10.1016/j.jff.2011.03.011.

ARES, G., GIMENEZ, A. and DELIZA, R. 2010a. Influence of three non-sensory factors on consumer choice of functional yogurts over regular ones. Food. Qual. Prefer. *21*, 361-367, DOI: 10.1016/j.foodqual.2009.09.002.

ARES, G., BARREIRO, C., DELIZA, R., GIMENEZ, A. and GAMBARO, A. 2010b. Consumer Expectations and Perception of Chocolate Milk Desserts Enriched with Antioxidants. J. Sens. Stud. *25*, 243-260, DOI: 10.1111/j.1745-459X.2010.00293.x.

ARES, G., BESIO, M., GIMENEZ, A. and DELIZA, R. 2010c. Relationship between involvement and functional milk desserts intention to purchase. Influence on attitude towards packaging characteristics. Appetite *55*, 298-304, DOI: 10.1016/j.appet.2010.06.016.

ARES, G., GIMENEZ, A. and GAMBARO, A. 2008. Uruguayan consumers' perception of functional foods. J. Sens. Stud. *23*, 614-630.

BAYARRI, S., MARTI, M., CARBONELL, I. and COSTELL, E. 2012. Identifying Drivers of Liking for Commercial Spreadable Cheeses with Different Fat Content. J. Sens. Stud. *27*, 1-11, DOI: 10.1111/j.1745-459X.2011.00362.x.

BECH-LARSEN, T. and SCHOLDERER, J. 2007. Functional foods in Europe: consumer research, market experiences and regulatory aspects. Trends Food Sci. Technol. *18*, 231-234, DOI: 10.1016/j.tifs.2006.12.006.

BOIAGO GOLLUECKE, A.P., DE SOUZA, J.C. and TAVARES, D.D.Q. 2008. Sensory stability of Concord and Isabel concentrated grape juices during storage. J. Sens. Stud. *23*, 340-353, DOI: 10.1111/j.1745-459X.2008.00159.x.

BURIN, V.M., FALCAO, L.D., GONZAGA, L.V., FETT, R., ROSIER, J.P. and BORDIGNON-LUIZ, M.T. 2010. Colour, phenolic content and antioxidant activity of grape juice. Ciencia Tecnol. Aliment. *30*, 1027-1032, DOI: 10.1590/S0101-20612010000400030.

CARRILLO, E., VARELA, P., SALVADOR, A. and FISZMAN, S. 2011. Main Factors Underlying Consumers' Food Choice: a First Step for the Understanding of Attitudes Toward "Healthy Eating". J. Sens. Stud. *26*, 85-95, DOI: 10.1111/j.1745-459X.2010.00325.x.

CHUNG, H.S., LEE, Y., RHEE, Y.K. and LEE, S. 2011. Consumer Acceptance of Ginseng Food Products. J. Food Sci. *76*, S516-S522, DOI: 10.1111/j.1750-3841.2011.02399.x.

DEAN, M., LAMPILA, P., SHEPHERD, R., ARVOLA, A., SABA, A., VASSALLO, M., CLAUPEIN, E., WINKELMANN, M. and LAHTEENMAKI, L. 2012. Perceived relevance and foods with health-related claims. Food. Qual. Prefer. *24*, 129-135, DOI: 10.1016/j.foodqual.2011.10.006.

DOOLEY, L., THRELFALL, R.T. and MEULLENET, J.F. 2012. Optimization of blended wine quality through maximization of consumer liking. Food Quality and Preference *24*, 40-47.

DROSSARD, C., FROHLING, B., BOLZENIUS, K., DIETRICH, H., KUNZ, C. and KERSTING, M. 2012. Liking of anthocyanin-rich juices by children and adolescents. Appetite *58*, 623-628.

FARIA, A. and CALHAU, C. 2011. The Bioactivity of Pomegranate: Impact on Health and Disease. Crit. Rev. Food Sci. Nutr. *51*, 626-634, DOI: 10.1080/10408391003748100.

FOLTS, J.D. 1998. Antithrombotic potential of grape juice and red wine for preventing heart attacks. Pharm. Biol. *36*, 21-27.

GACULA, M.C. 1993. Design and analysis of sensory optimization. Food & Nutrition Press, U.S.A.

GRACIA, A., LOPEZ, B. and VIRUE, S. 2011. Willingness to pay for natural juice: a choice experiment approach. Itea-Informacion Tecnica Economica Agraria *107*, 21-32.

ISHIMOTO, H., SHIBATA, M., MYOJIN, Y., ITO, H., SUGIMOTO, Y., TAI, A. and HATANO, T. 2011. In vivo anti-inflammatory and antioxidant properties of ellagitannin metabolite urolithin A. Bioorg. Med. Chem. Lett. *21*, 5901-5904, DOI: 10.1016/j.bmcl.2011.07.086.

JOSEPH, J.A., SHUKITT-HALE, B., DENISOVA, N.A., BIELINSKI, D., MARTIN, A., MCEWEN, J.J. and BICKFORD, P.C. 1999. Reversals of age-related declines in neuronal signal transduction, cognitive, and motor behavioral deficits with blueberry, spinach, or strawberry dietary supplementation. Journal of Neuroscience *19*, 8114-8121.

JOSEPH, J.A., SHUKITT-HALE, B., DENISOVA, N.A., PRIOR, R.L., CAO, G., MARTIN, A., TAGLIALATELA, G. and BICKFORD, P.C. 1998. Long-term dietary strawberry, spinach, or vitamin E supplementation retards the onset of age-related neuronal signal-transduction and cognitive behavioral deficits. Journal of Neuroscience *18*, 8047-8055.

KELEBEK, H. and SELLI, S. 2011. Evaluation of chemical constituents and antioxidant activity of sweet cherry (Prunus avium L.) cultivars. Int. J. Food Sci. Technol. *46*, 2530-2537, DOI: 10.1111/j.1365-2621.2011.02777.x.

KOAK, J.H., KANG, B.S., HAHM, Y.T., PARK, C.S., BAIK, M.Y. and KIM, B.Y. 2010. Blending of Different Domestic Grape Wines Using Mixture Design and Optimization Technique. Food Science and Biotechnology *19*, 1011-1018, DOI: 10.1007/s10068-010-0142-7.

KOPPEL, K. and CHAMBERS, E. 2010. Development and Application of a Lexicon to Describe the Flavor of Pomegranate Juice. J. Sens. Stud. *25*, 819-837, DOI: 10.1111/j.1745-459X.2010.00307.x ER.

KRIKORIAN, R., NASH, T.A., SHIDLER, M.D., SHUKITT-HALE, B. and JOSEPH, J.A. 2010. Concord grape juice supplementation improves memory function in older adults with mild cognitive impairment. Br. J. Nutr. *103*, 730-734, DOI: 10.1017/S0007114509992364.

LAWLESS, L.J.R., THRELFALL, R.T., HOWARD, L.R. and MEULLENET, J.-F. 2012 in press. Sensory, compositional, and color properties of nutraceutical-rich juice blends. American Journal of Enology and Viticulture *63*.

LEE, J., CHAMBERS, E., CHAMBERS, D.H., CHUN, S.S., OUPADISSAKOON, C. and JOHNSON, D.E. 2010. Consumer Acceptance for Green Tea by Consumers in the United States, Korea and Thailand. J. Sens. Stud. *25*, 109-132, DOI: 10.1111/j.1745-459X.2010.00287.x.

LEKSRISOMPONG, P.P., WHITSON, M.E., TRUONG, V.D. and DRAKE, M.A. 2012. Sensory Attributes and Consumer Acceptance of Sweet Potato Cultivars with Varying Flesh Colors. J. Sens. Stud. *27*, 59-69, DOI: 10.1111/j.1745-459X.2011.00367.x.

MENA, P., GARCIA-VIGUERA, C., NAVARRO-RICO, J., MORENO, D.A., BARTUAL, J., SAURA, D. and MARTI, N. 2011. Phytochemical characterisation for industrial use of pomegranate (Punica granatum L.) cultivars grown in Spain RID G-4379-2011. J. Sci. Food Agric. *91*, 1893-1906, DOI: 10.1002/jsfa.4411.

MEULLENET, J.-., XIONG, R. and FINDLAY, C.J. 2007. Multivariate and probabilistic analyses of sensory science problems. IFT Press and Blackwell Publishing, U.S.A.

MOKDAD, A.H., MARKS, J.S., STROUP, D.F. and GERBERDING, J.L. 2004. Actual causes of death in the United States, 2000. Jama-Journal of the American Medical Association *291*, 1238-1245.

OLSEN, N.V., MENICHELLI, E., SORHEIM, O. and NAES, T. 2012. Likelihood of buying healthy convenience food: An at-home testing procedure for ready-to-heat meals. Food. Qual. Prefer. *24*, 171-178, DOI: 10.1016/j.foodqual.2011.11.001.

RANCELIENE, V., VYSNIAUSKIENE, R., ANISIMOVIENE, N., SIKSNIANAS, T. and STANYS, V. 2009. The effect of cherry fruit extracts on meristematic plant cells. Zemdirbyste *96*, 58-66.

ROWE, C.A., NANTZ, M.P., NIEVES, C., JR., WEST, R.L. and PERCIVAL, S.S. 2011. Regular Consumption of Concord Grape Juice Benefits Human Immunity. J. Med. Food *14*, 69-78, DOI: 10.1089/jmf.2010.0055.

SABBE, S., VERBEKE, W., DELIZA, R., MATTA, V. and VAN DAMME, P. 2009. Effect of a health claim and personal characteristics on consumer acceptance of fruit juices with different concentrations of acai (Euterpe oleracea Mart.) RID F-8373-2010. Appetite *53*, 84-92, DOI: 10.1016/j.appet.2009.05.014.

SEERAM, N.P., ADAMS, L.S., ZHANG, Y., LEE, R., SAND, D., SCHEULLER, H.S. and HEBER, D. 2006. Blackberry, black raspberry, blueberry, cranberry, red raspberry, and strawberry extracts inhibit growth and stimulate apoptosis of human cancer cells in vitro. J. Agric. Food Chem. *54*, 9329-9339, DOI: 10.1021/jf061750g.

SEERAM, N.P., AVIRAM, M., ZHANG, Y., HENNING, S.M., FENG, L., DREHER, M. and HEBER, D. 2008. Comparison of antioxidant potency of commonly consumed polyphenol-rich beverages in the united states. J. Agric. Food Chem. *56*, 1415-1422, DOI: 10.1021/jf073035s.

SHALLENBERGER, R.S. 1993. Taste Chemistry. Blackie Academic & Professional, Cambridge, Great Britain.

SIEGRIST, M., STAMPFLI, N. and KASTENHOLZ, H. 2008. Consumers' willingness to buy functional foods. The influence of carrier, benefit and trust. Appetite *51*, 526-529, DOI: 10.1016/j.appet.2008.04.003.

SINGLETARY, K.W., JUNG, K. and GIUSTI, M. 2007. Anthocyanin-rich grape extract blocks breast cell DNA damage. J. Med. Food *10*, 244-251, DOI: 10.1089/jmf.2006.258.

SLINKARD, K. and SINGLETON, V.L. 1977. Total Phenol Analysis - Automation and Comparison with Manual Methods. Am. J. Enol. Vitic. *28*, 49-55.

STEPHENS, G. 2008. Baby Boomers and the Role of Nutraceutical Ingredients. Cereal Foods World *53*, 306-307, DOI: 10.1094/CFW-53-60.

THRELFALL, R.T., MORRIS, J.R., MEULLENET, J.F. and STRIEGLER, R.K. 2007. Sensory characteristics, composition, and nutraceutical content of juice from Vitis rotundifolia (Muscadine) cultivars. Am. J. Enol. Vitic. *58*, 268-273.

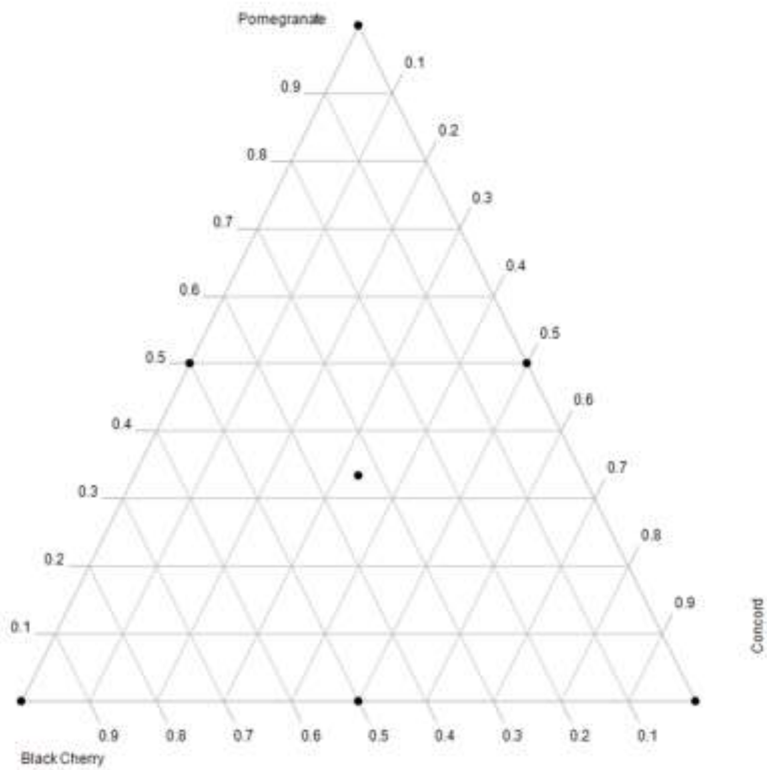
TUORILA, H., HUOTILAINEN, A., LAHTEENMAKI, L., OLLILA, S., TUOMI-NURMI, S. and URALA, N. 2008. Comparison of affective rating scales and their relationship to variables reflecting food consumption. Food Qual. Prefer. *19*, 51-61, DOI: 10.1016/j.foodqual.2007.06.007.

VERBEKE, W. 2005. Consumer acceptance of functional foods: socio-demographic, cognitive and attitudinal determinants RID F-8373-2010. Food Qual. Prefer. *16*, 45-57, DOI: 10.1016/j.foodqual.2004.01.001.

VIDIGAL, M.C.T.R., MINIM, V.P.R., CARVALHO, N.B., MILAGRES, M.P. and GONCALVES, A.C.A. 2011. Effect of a health claim on consumer acceptance of exotic Brazilian fruit juices: Acai (Euterpe oleracea Mart.), Camu-camu (Myrciaria dubia), Caja (Spondias lutea L.) and Umbu (Spondias tuberosa Arruda). Food Res. Int. *44*, 1988-1996, DOI: 10.1016/j.foodres.2010.11.028.

XIONG, R. and MEULLENET, J. 2006. A PLS dummy variable approach to assess the impact of jar attributes on liking. Food Qual. Prefer. *17*, 188-198, DOI: 10.1016/j.foodqual.2005.03.006.

FIG. 1. SIMPLEX CENTROID DESIGN



Black Cherry	Concord Grape	Pomegranate
1	0	0
0	1	0
0	0	1
0.50	0.50	0
0.50	0	0.50
0	0.50	0.50
0.33	0.33	0.33

TABLE 1. JUICE PURCHASE FREQUENCY

	Pomegranate Juice	Black Cherry Juice	Concord Grape Juice
1-7 days ago	40	32	59
8-30 days ago	42	36	27
31-365 days ago	14	20	13
More than 365 days ago	3	8	1
Never	1	4	0

TABLE 2. ANTIOXIDANT COMPOSITE AND COMPOSITIONAL ANALYSES[a,b,c]

Blend	Antioxidant Composite	Antioxidant Composite Ranking	Total Phenolics (ml/100g)
100%Con	61.7	5	40.7b
50%BlkCh+50%Con	54.1	6	28.1e
33%Con+33%Pom+33%BlkCh	67.3	4	36.9c
50%Con+50%Pom	78.8	2	45.9a
50%BlkCh+50%Pom	71.2	3	32.5d
100%BlkCh	46.5	7	14.4f
100%Pom	95.8	1	47.7a
Optimized Blend	n/a	n/a	39.4bc

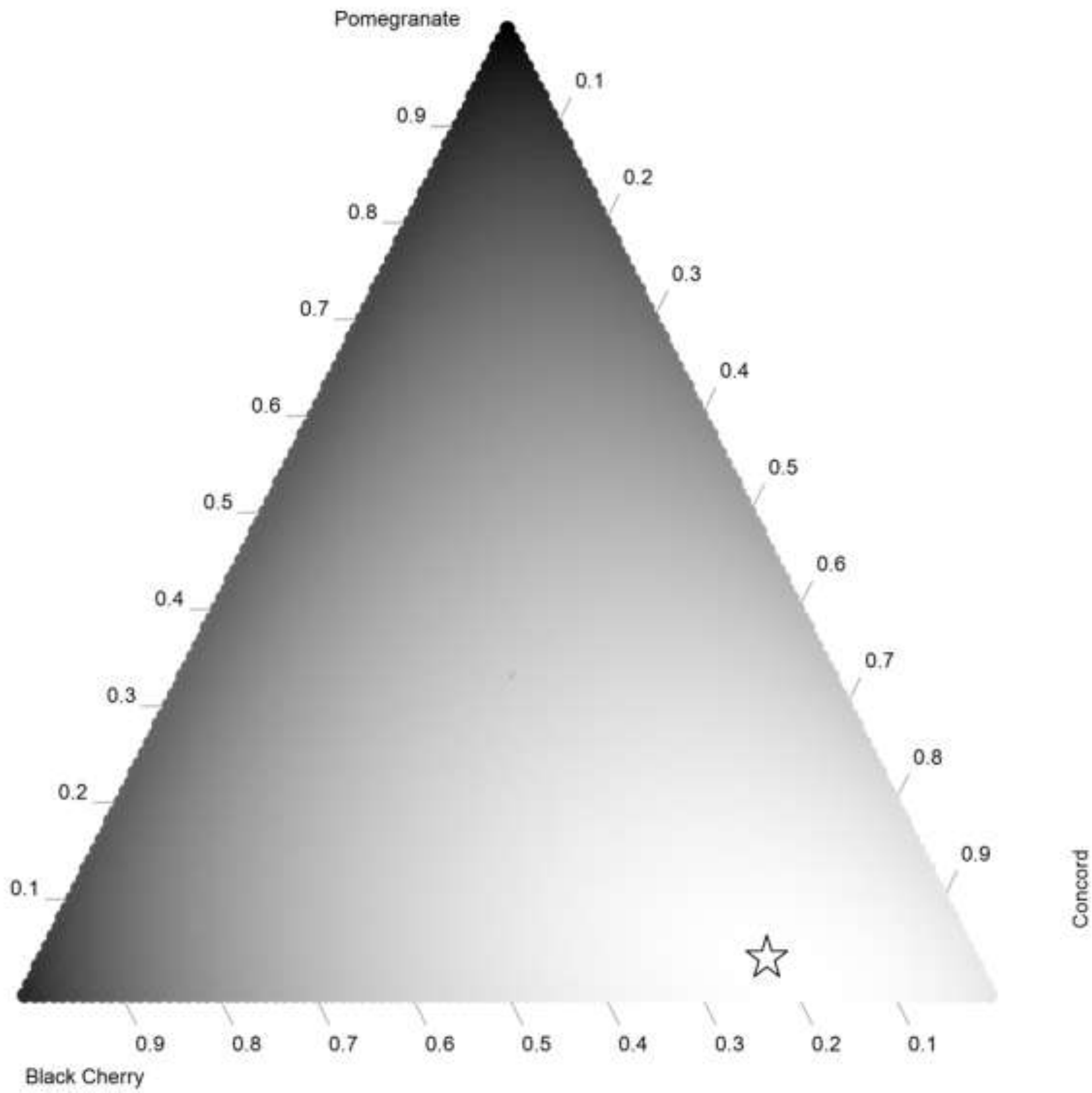
[a]Black Cherry (BlkCh), Concord grape (Con), Pomegranate (Pom)
[b]Composites were based on published antioxidant composites for pomegranate juice (95.8), black cherry juice (46.5), and Concord grape juice (61.7) developed from multiple antioxidant assays and juice brands (Seeram *et al.* 2008)
[c]Rankings (1-7) are based on averaged antioxidant composites

TABLE 3. OVERALL LIKING[a]

	Overall Liking Pre-Information	Overall Liking Post-Information	Paired T-Test[b,c]	Post-information Purchase Intent
100%Concord (Con)	7.63a	7.48a	Shift Downward	3.75a
50%BlkCh+50%Con	7.35ab	7.07a	Shift Downward	3.66a
33%Con+33%Pom+33%BlkCh	7.14ab	7.13a	Not Significant	3.51a
50%Con+50%Pom	6.72b	6.99a	Shift Upward	3.03b
50%BlkCh+50%Pom	5.81c	6.01b	Shift Upward	2.54c
100%Black cherry (BlkCh)	5.32c	5.01c	Shift Downward	2.33c
100%Pomegranate (Pom)	4.55d	5.01c	Shift Upward	1.85d
Optimized Blend[d]	7.74[e]	7.55[f]	n/a	n/a

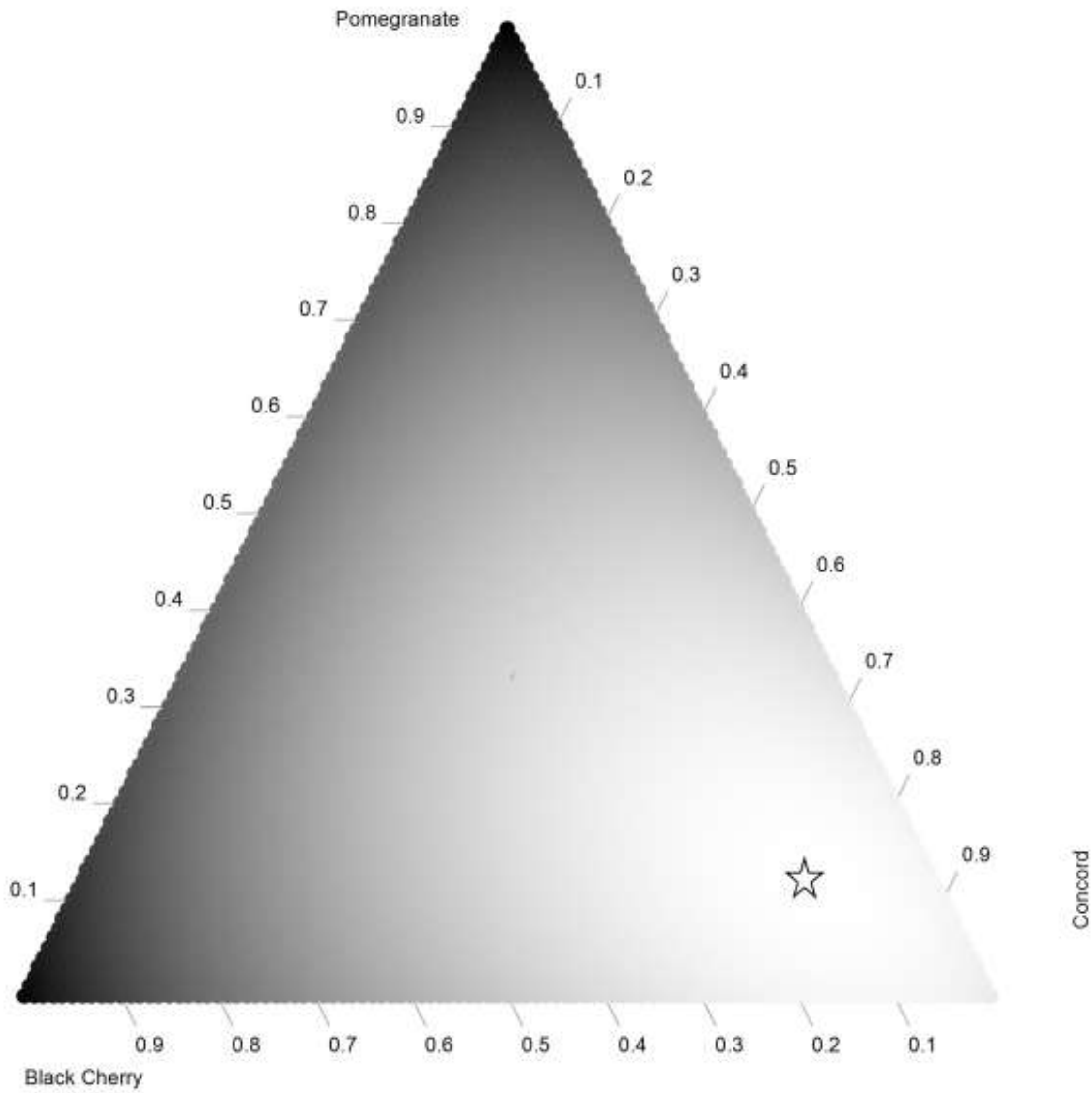
[a]Letters denote within column significant difference according to Tukey's HSD at p<0.05
[b]T-test is significant at p<0.001. T-test demonstrates effect of antioxidant information on overall liking.
[d]Overall liking for optimized blends is based on desirability function and prediction formulas
[e]Estimated for 77%Con+3%Pom+20%BlkCh
[f]Estimated for 75%Con+12%Pom+13%BlkCh

FIG. 2. PRE-INFORMATION DESIRABILITY PLOT[a,b]



[a]White (higher desirability) to black (lower desirability) shading indicates desirability
[b]Star indicates optimized solution (77%Concord+3%Pomegranate+20%Black Cherry)

FIG. 3. POST-INFORMATION DESIRABILITY PLOT[a,b]



[a]White (higher desirability) to black (lower desirability) shading indicates desirability

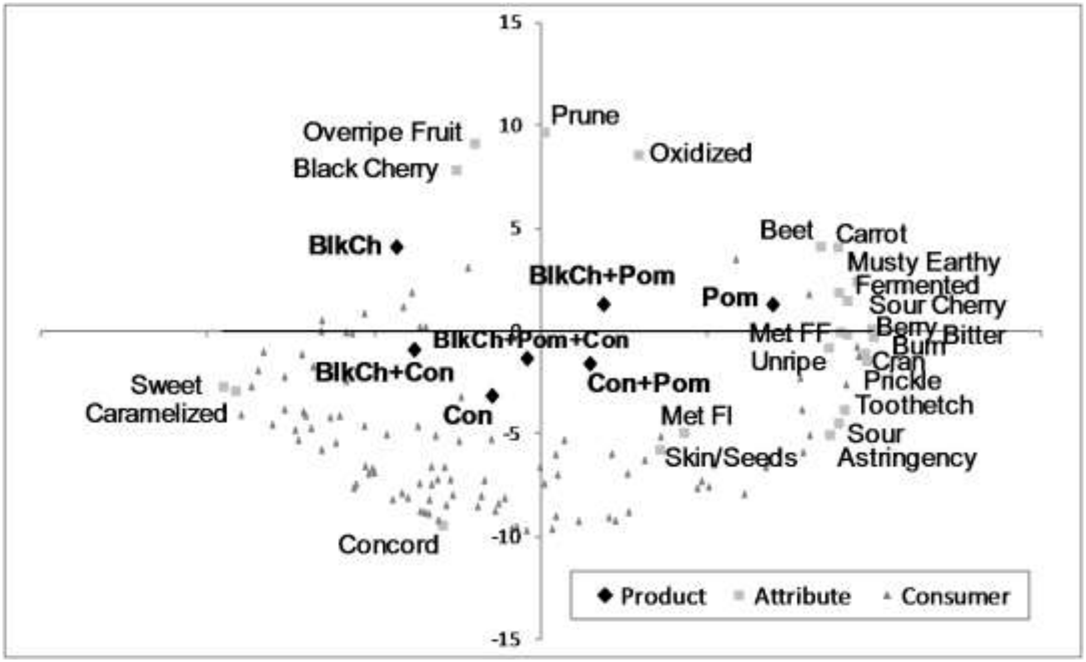
[b]Star indicates optimized solution (75%Concord+12%Pomegranate+13%Black Cherry)

TABLE 4. CORRELATIONS OF JUICE TREATMENT ATTRIBUTES[a]

	Overall Liking Pre-Information	Overall Liking Post-Information	Purchase Intent	Price	Antioxidant Composite
Overall Liking Pre-Information	1.00				
Overall Liking Post-Information	0.97	1.00			
Purchase Intent	0.99	0.95	1.00		
Price	-0.56	-0.35	-0.59	1.00	
Antioxidant Composite	-0.43	-0.20	-0.46	0.98	1.00

[a]Shaded cells indicate significance at <0.01.

FIG. 4. EXTERNAL PREFERENCE MAPPING OF NUTRACEUTICAL JUICE TREATMENTS[a,b]



[a]Black Cherry (BlkCh), Concord Grape (Con), Pomegranate (Pom)
[b]Abbreviations for attributes: Throat Burn (Burn), Cran (Cranberry), Prickle (Prickle Bite), Metallic Flavor (Met Fl), Metallic (feeling factor) (Met FF), Unripe Fruit (Unripe), Other Berry (Berry)

TABLE 5. PARTIAL LEAST SQUARES REGRESSION (PLSR) COEFFICIENTS FOR CONVERTED JUST-ABOUT-RIGHT VARIABLES[a]

	Intercept	Too Sweet	Not Sweet Enough	Too Sour	Not Sour Enough	Too Much Pom Flavor	Not Enough Pom Flavor	Too Much Concord Flavor	Not Enough Concord Flavor	Too Much BlkCh Flavor	Not Enough BlkCh Flavor	Too Astringent	Not Astringent Enough	Too Bitter	Not Bitter Enough
100%Black Cherry (BlkCh)	7.09	-0.39	0.73	-0.60	0.44	-0.39	0.42	-0.19	0.53	-0.38	0.28	-0.20	0.32	-0.62	0.33
100%Concord (Con)	8.15	-0.34	0.09	-0.44	0.12	-0.09	0.16	-0.30	0.09	-0.07	0.30	-0.56	0.08	-0.29	0.13
100%Pomegranate (Pom)	7.64	-0.01	0.64	-0.67	0.06	-0.37	0.03	-0.06	0.23	-0.07	0.18	-0.38	0.06	-0.70	0.00
33%BlkCh+33%Con+ 33%Pom	7.91	-0.19	0.55	-0.51	0.13	-0.39	0.09	-0.13	0.33	-0.04	0.12	-0.63	-0.09	-0.66	0.02

[a]Shading indicates significance of the variable in the PLSR model

CHAPTER 8

Effects of Time Preference, Risk Preference, and Attributes Not "Just-about-right" on Consumer Willingness-to-pay for Nutraceutical-rich Juice

Lydia J.R. Lawless, Andreas C. Drichoutis, Rodolfo M. Nayga, Jr.,
Renee T. Threlfall, Jean-François Meullenet

Formatted for Food Quality and Preference

ABSTRACT

Nutraceutical juice is a prime candidate for the growing nutraceutical market due to its inherent healthfulness and convenience. A non-hypothetical Becker–DeGroot–Marschak (BDM) mechanism was utilized to determine consumers' willingness-to-pay (WTP) for 32 ounces of an antioxidant-rich juice blend (75%Concord+12%Pomegranate+13%Black Cherry) created based on nutraceutical and sensory attributes. Non-hypothetical decision-making tasks were used to ascertain the effects of time preference (i.e., level of future orientation) and risk aversion on WTP. For the time preference tasks, participants were given a series of ten choices in which they had to indicate their preferences (e.g., Choice Set 1: $300 in one month vs. $304 in three months). For the risk aversion tasks, participants similarly chose between two gambles (e.g., Choice Set 1: 10% chance of winning $2, 90% of winning $1.60 vs. 10% chance of winning $3.85, 90% of winning $0.10). Time and risk preferences were then calculated. Participants (n=228) were divided into four treatment groups (control, antioxidant information only, sensory evaluation only, and sensory evaluation with antioxidant information) and indicated their WTPs during two bidding rounds. Average WTP for the juice blend was $3.45, and average overall liking (OL) was 7.42. Antioxidant information and time preference influenced bidding behavior. For treatment groups who tasted the product, just-about-right (JAR) data were converted to dummy variables and regressed against WTP and OL. The coefficients for WTP and OL were similarly affected by variables not JAR (sweetness, black cherry flavor, and bitterness). WTP increased $0.25 per every unit increase in sweetness toward JAR, $0.20 per every unit decrease in black cherry flavor toward JAR, and $0.29 per every unit decrease in bitterness toward JAR. Experiments using the BDM mechanism offer realistic consumer valuations because they are conducted in a non-hypothetical setting. Measuring the effects of time and risk preferences on WTP for nutraceutical-juice offers novel insights about consumer psychology.

Keywords: experimental auction, risk aversion, time preference, just about right, willingness to pay, optimization

INTRODUCTION

There are increasing concerns among consumers (particularly aging consumers) about nutrition and health issues (Nayga, 2008; Stephens, 2008). Consequently, the food industry is striving to offer healthier alternatives to consumers. The emphasis that consumers place on sensory attributes versus nutraceutical attributes can be assessed through valuation tasks such as experimental auctions, which measure willingness-to-pay (WTP). Experimental auctions are non-hypothetical and incentive compatible, which means that participants have the incentive to reveal their true preferences. Mechanisms such as the second-price auction or the Becker–DeGroot–Marschak (BDM) mechanism[1] have previously been applied to evaluate the value of apple freshness, enhanced safety of infant formula, and information about nutrients in grass-fed beef (Goldberg, Roosen, and Nayga, 2009; Lund, Jaeger, Amos, Brookfield, and Harker, 2006; Xue, Mainville, You, and Nayga, 2010). Elicited valuations among mechanisms have been examined by a number of papers (Lusk, Feldkamp, and Schroeder, 2004; Noussair, Robin, and Ruffieux, 2004; Shahrabani, Benzion, and Shavit, 2008). Typically, the BDM mechanism is considered less competitive because all participants could potentially buy a unit of the product whereas in the second price auction, only one individual can win[2]. Valuation tasks are non-hypothetical because the winner(s) of the experimental mechanism actually pays for a unit of the product. Although consumer overall liking and purchase intent may offer some information about the potential success of a product, non-hypothetical WTP has the added advantage of requiring the consumer to follow through with his/her stated intentions. A consumer may report

[1] The BDM is not an auction per se but is often grouped together with other auction mechanisms due to its similarity in procedures.
[2] In a 2nd price auction, individuals interact with each other in determining the 2nd highest price and the winner of the auction, whereas the BDM mechanism does not involve interaction with other subjects.

high overall liking but only intend to buy the product at a very low price point. With valuation tasks, the price point at which the consumer is willing to purchase the product is identified during the experiment.

Attitudinal factors and some demographics have been associated with purchase intent, acceptance, and WTP for nutraceuticals. Information-searching rational food consumers, novelty-seeking adventurous consumers, and conservative consumers who presently consume functional foods are especially desirable consumers to target with new functional products according to survey data from Hungary (Szakaly, Szente, Koever, Polereczki, and Szigeti, 2012). More specifically, Onwezen and Bartels (2011) identified three cross-cultural consumer segments who all responded positively to a hypothetical functional peach that reduced cholesterol. Concerns about chronic diseases have also been found to significantly influence purchase intent for food products such as conjugated linoleic acid (CLA)-enhanced dairy products (Peng, West, and Wang, 2006). Demographics such as children in the household and attitudes associated with health-consciousness predicted WTP for CLA-enhanced, "cancer fighting" dairy products (Maynard and Franklin, 2003). Hypothetical surveys of Canadian consumers found that many were willing to pay premiums for nutraceuticals (West, Gendron, Larue, and Lambert, 2002). These findings suggest that consumers may be willing to pay more for nutraceutical-juice based on a description of its functional properties. Further investigating and identifying demographic and attitudinal characteristics of potential nutraceutical consumers facilitates better marketing and positioning of new products.

In addition to demographics and attitudes, psychological factors may influence consumer preferences. In particular, risk and time preferences may influence consumer WTP for potentially health-supporting nutraceuticals, but these factors have not been examined in past studies dealing with WTP for functional foods.

Time preference is a measure of future orientation and is quantified with the time discount rate, which can be estimated with exponential or hyperbolic models among others (Frederick, Loewenstein, and O'Donoghue, 2002). Higher time discount rates indicate less future orientation. Conceivably, highly future-oriented individuals (i.e., those with low time discount rates) may be willing to pay more for health-maintaining products. To elicit time discount rates in the laboratory, consumers may be asked to make a series of choices between smaller, more immediate rewards and larger, delayed rewards (Andersen, Harrison, Lau, and Rutstrom, 2008; Coller, and Williams, 1999; Harrison, Lau, and Williams, 2002). In order to motivate consumers to reveal their true preferences, a fraction of participants may be selected to have one of their preferences come to fruition.

Risk aversion refers to an individual's preference for a smaller, more certain reward rather than a larger, less certain reward. Risk preferences can be classified as risk-averse, risk - neutral, or risk-loving. In tasks such as those utilized by (Andersen, Harrison, Lau, and Rutstrom, 2008; Holt and Laury, 2002), an individual faces a series of choices between two gambles, one riskier but with a potentially larger reward and one less risky with a smaller reward. As the individual progresses through the exercise, the chances of receiving the larger gamble improve. The point at which an individual switches from the less risky gamble to the riskier one can be used as an indication of risk preference. Potentially, individuals who are more risk averse may be willing to pay more for products that are supportive of health.

A novel black cherry, Concord grape, and pomegranate juice blend previously optimized on nutraceutical and sensory attributes may offer value to health-conscious consumers because black cherry, Concord grape, and pomegranate juices are polyphenol- and antioxidant-rich (Seeram, Aviram, Zhang, Henning, Feng, Dreher, et al, 2008). Polyphenolics include anthocyanins (abundant in black cherries and Concord grapes) and ellagitannins (abundant in pomegranates), which have been associated with antioxidant, anticarcinogenic, antimutagenic, neurologically-protective, and pro-immunity effects (Guo, Wei, Yang, Xu, Pang, and Jiang, 2008; Kim, Heo, Kim, Yang, and Lee, 2005; Krikorian, Nash, Shidler, Shukitt-Hale, and Joseph, 2010; Lansky, Harrison, Froom, and Jiang, 2005; Lansky, Jiang, Mo, Bravo, Froom, Yu, et al, 2005; Munoz-Espada, Wood, Bordelon, and Watkins, 2004; Pacheco-Palencia, Noratto, Hingorani, Talcott, and Mertens-Talcott, 2008; Rowe, Nantz, Nieves, West, and Percival, 2011; Usenik, Fabcic, and Stampar, 2008).

Consumers may indeed assign differing importance to nutraceutical and taste attributes. Similarly, some sensory attributes may contribute more to WTP than others. Thus, in addition to estimation of risk and time preferences, the effects of specific attributes on WTP were assessed. Partial least squares regression (PLSR) has been applied to determine the influence of specific attributes (as measured by a descriptive panel) on overall liking (Meullenet, Xiong, and Findlay, 2007). The use of PLSR was expanded to determine the influence of converted just-about-right attributes on overall liking (Xiong and Meullenet, 2006). Converting each JAR attribute to a set of two dummy variables, one which represents the *too much* side and one which represents the *too little* side of an attribute, allows the JAR scale to be balanced similarly to hedonic scales (Xiong and Meullenet, 2006). Without conversion, the optimum level of a JAR attribute is in the middle of the scale, whereas the optimum level of hedonic scales is at the top of the scale. Converting JAR variables to sets of continuous variables as proposed by Xiong et al. (2006) and using WTP (instead of overall liking) as the response allows the experimenter to identify the effect of an attribute not being JAR on WTP. Results could identify attributes most important to the consumer in terms of WTP, which could have implications for repurchase behavior. Additionally, using non-hypothetical WTP instead of overall liking has the added advantage of using a response variable that is based on revealed rather than stated preferences.

The objectives of this research were to 1) describe attitudinal factors associated with WTP for nutraceuticals, 2) identify significant predictors of WTP, and 3) describe the penalty in dollars and overall liking for variables not JAR.

MATERIALS AND METHODS

2.1 Product

The formulation of the optimized juice blend (i.e., 75% Concord juice, 13% black cherry juice, and 12% pomegranate juice) was determined through previous consumer-oriented choice and mixture experimental designs. Consumers evaluated antioxidant status and sensory properties of a range of juice formulations during a central location test. The optimized formula was determined through using overall liking scores in a desirability function, which has been used previously to determine optimum wine blends (Dooley, Threlfall, and Meullenet, 2012).

Black cherry (Kerr Concentrates, Inc., Salem, OR, 68% soluble solids), Concord grape (FruitSmart, Grandview, WA, 66.5% soluble solids), and pomegranate (Kerr Concentrates, Inc., Salem, OR, 63.7% soluble solids) juice concentrates were reconstituted to 16.5% soluble solids, bottled, and pasteurized in the University of Arkansas Pilot Plant. The juice blend was pasteurized to 90°C in 32 oz bottles, which were comparable to other commercial juices.

2.2 Panelists

Panelists (n=228) were recruited from the University of Arkansas Sensory Service Center database based on juice consumption (three times per week) and liking of black cherries, Concord grapes, and pomegranates. Panelists received monetary compensation in the form of a gift card for their participation; they were asked to bring $10 in case they were required to purchase the juice.

2.3 Experimental Design

The moderator gave written and oral instructions and led a candy bar practice valuation task to familiarize consumers with the BDM mechanism. The candy bar practice valuation task was hypothetical to avoid demand reduction effects, but the juice valuation task using the BDM mechanism was non-hypothetical, meaning winners had to pay cash for the juice blend.

For the juice experiment, the BDM mechanism with two bidding rounds was used. Bidding rounds were used to elicit the learning effect (i.e., under which participants learn more about their true WTP through experience with the mechanism) and create more observations. Participants were not given market feedback (i.e., information about what other people were bidding) between rounds. The binding round was randomly selected in each session.

Average reference prices for 32 oz bottles were given for 100% black cherry juice ($5.11), 100% Concord juice ($2.10), and 100% pomegranate juice ($8.57) for informational purposes. The optimization process was also explained to consumers.

For the BDM mechanism, a price distribution was established based on the endpoints of the highest and lowest reference prices ($2.10 and $8.57). For each session, a price was randomly drawn from this distribution. Participants who had WTPs higher than the drawn price in the binding round were considered winners of the valuation task, and they purchased the juice blend at the drawn price. Participants who had equal or lower WTPs in the binding round compared to the drawn price did not purchase the product. Since consumers did not know the endpoints of the price distribution, they were motivated to bid their true WTP.

The experiment utilized a between subjects design with four treatment groups (Figure 1). The original experimental design included four sessions of each treatment with participants evenly distributed in each session; however, make-up sessions were held for treatment groups with low-turnout.

Treatment group 1 (Info) received the following information about the juice blend: *This juice blend is rich in polyphenolic antioxidants, which are thought to support health.* This information statement is conservatively written due to the United States Federal Trade Commission's and United States Food and Drug Administration's criticisms of specific health claims for juice (Dokoupil, 2008; Mundy, 2010). Treatment group 2 (Taste) evaluated sensory attributes of the juice blend. Treatment group 3 (InfoTaste) evaluated the sensory properties of the juice blend and received the antioxidant information. The control group (Control) neither tasted nor received information about the juice blend.

After the completion of the juice valuation task, consumers were asked to complete a questionnaire. Part of the questionnaire included a series of risk and time preference tasks (Appendix 5.1 and 5.2). In order to relieve potential confusion about the time and risk preference tasks, a second set of instructions was given to consumers. The moderator explained that for each row, participants had to indicate whether they preferred Option A or Option B. The order of the risk and time preference tasks and the order in which each participant received the subtasks (3 month time horizon vs. 6 month time horizon, 1x risk task vs. 10x risk task) were randomized. The moderator also stressed that all participants had a 10% chance of having one of their preferences awarded. Consumers who were selected in the 10% received a gift card that represented their corresponding preferred amount and time point.

The post-valuation-task questionnaire also included a series of health-related statements. The content of the statements was determined with guidance from previous fruit juice projects (Deliza, MacFie, and Hedderley, 2003; Lawless, Nayga, Akaichi, Meullenet, Threlfall, and Howard, 2012, in press). Respondents indicated their agreement to each statement based on a 5-point Likert scale anchored by *strongly disagree* and *strongly agree*.

Demographics such as household size, age, income, education, marital status, employment status, and gender were included. Mood, exercise frequency, home inventory of juice, and fruit juice consumption habits questions were also asked.

2.4 Consumer Sensory Evaluation

During the post-valuation-task questionnaire, treatment groups 2 and 3 (Taste and TasteInfo groups respectively) were served two ounces of the juice blend to taste. Consumers evaluated overall liking with the 9-point verbal hedonic scale and diagnostic variables (sweetness, sourness, pomegranate flavor, Concord grape flavor, black cherry flavor, astringency, bitterness) with 5-point just-about-right scales. Treatment groups 1 and 4 (Info and Control) evaluated overall liking based on the information they were provided with the 9-point hedonic scale.

2.5 Statistical Analysis

Treatment groups were initially compared with t-test analysis (JMP 9.0.2, Cary, NC). Initial analysis included hierarchical cluster analysis with Ward's criterion, which did not reveal segmentation for WTP or OL based on agreement to health-oriented statements (JMP 9.0.2, Cary, NC). Landscape segmentation analysis (LSA) was used to describe agreement among health-oriented statements (IFPrograms 7.9, Richmond, VA). Panelists with low variance were excluded. Correlations between average WTP and agreement with health-oriented statements were performed by treatment (JMP 9.0.2, Cary, NC).

2.5.1 WTP Regression Modeling

Random effects regression was performed using relative risk aversion, discount rates, treatment variables (Taste, Info, InfoTaste, Control), and other covariates that could potentially influence WTP (Stata 11.0, College Station, Texas).

Relative risk aversion and discount rates were estimated from a joint model of risk and time preferences. Precise inferences about discount rates can only be made once the curvature of the utility function is identified, and the risk preference task allows one to estimate the curvature. Andersen et al. (2008) showed that it is essential to have one experimental task for measuring the curvature of the utility function, another task to identify the discount rate conditional on knowing the utility function, and then jointly estimate the structural model defined over the parameters of the utility function and discount rate.

We start by assuming that the utility function is the constant relative risk aversion (CRRA) specification:

$$U(M) = \frac{M^{1-r}}{1-r} \qquad (1)$$

for $r \neq 1$, where r is the CRRA coefficient. In (1), $r=0$ denotes risk neutral behavior, $r>0$ denotes risk aversion behavior and $r<0$ denotes risk loving behavior.

In addition, if we assume that Expected Utility Theory (EUT) holds for the choices over risky alternatives and that discounting is exponential, then the subject is indifferent between two income options M_t and $M_{t+\tau}$ if and only if:

$$U(M_t) = \frac{1}{(1+\delta)^{\tau}} U(M_{t+\tau}) \qquad (2)$$

where $U(M_t)$ is the utility of monetary outcome M_t for delivery at time *t*, δ is the discount rate, τ is the horizon for delivery of the later monetary outcome at time $t+\tau$, and the utility function is separable and stationary over time. δ is the discount rate that equalizes the present value of the two monetary outcomes in the indifference condition (2). The contribution to the overall likelihood from the risk aversion responses can be written for each lottery *i* as:

$$EU_i = \sum_{j=1,2} p(M_j) \cdot U(M_j) \qquad (3)$$

where $p(M_j)$ are the probabilities for each outcome M_j that are induced by the experimenter. To specify the likelihoods conditional on the model, a stochastic specification from Holt and Laury (2002) is used. The expected utility (EU) for each lottery pair is calculated for the candidate estimate of *r* and the ratio:

$$\nabla EU = (EU_B - EU_A)/\mu \qquad (4)$$

is then calculated where EU_A and EU_B refer to options A and B respectively, and μ is a structural noise parameter used to allow some errors. The index in (4) is linked to the observed choices using a standard cumulative normal distribution function $\Phi(\nabla EU)$, which transforms the argument into a probability statement. Wilcox (2011) proposed the "contextual error" specification whereas instead of the latent index in (4), we have:

$$\nabla EU = ((EU_B - EU_A)/c)/\mu \qquad (5)$$

In (5) *c* is a new normalizing term for each lottery pair A and B. The normalizing term is defined as the maximum utility over all prizes in this lottery pair minus the minimum utility over all prizes in this lottery pair. Since the value of *c* varies between lottery choices, it is said to be "contextual." The conditional log-likelihood can then be written as:

$$\ln L^{RA}(r,\mu;y,\mathbf{X}) = \sum_i \left[\left(\ln \Phi(\nabla EU) \mid y_i = 1\right) + \left(\ln\left(1-\Phi(\nabla EU)\right) \mid y_i = -1\right) \right] \quad (6)$$

where $y_i = 1\ (-1)$ denotes the choice of the option B (A) lottery in the risk preference task *i*. Subjects were allowed to express indifference between choices and were told that if that choice was selected to be played out, one of the two options would be randomly selected as binding. Thus the likelihood for these choices can be modified such that choices imply a 50/50 mixture of the likelihood of choosing either lottery:

$$\ln L^{RA}(r,\mu;y,\mathbf{X}) = \sum_i \left(\begin{array}{l} \left(\ln \Phi(\nabla EU) \mid y_i = 1\right) + \left(\ln\left(1-\Phi(\nabla EU)\right) \mid y_i = -1\right) \\ + \left(\frac{1}{2} \ln \Phi(\nabla EU) + \frac{1}{2} \ln\left(1-\Phi(\nabla EU)\right) \mid y_i = 0 \right) \end{array} \right) \quad (7)$$

Despite the intuitive and conceptual appeal of EUT, a number of experiments suggest that EUT often fails as a descriptive model of individual behavior. A popular alternative to EUT, is the Rank Dependent Utility (RDU) (Quiggin, 1982), which was incorporated into Tversky and Kahneman's (1992) cumulative prospect theory. RDU extends the EUT model by allowing for non-linear probability weighting associated with lottery outcomes. To calculate decision weights under RDU, one replaces expected utility in equation (3) with:

$$EU_i = \sum_{j=1,2} w\left(p(M_j)\right) \cdot U(M_j) = \sum_{j=1,2} w_j \cdot U(M_j) \quad (8)$$

where $w_2 = w(p_2+p_1) - w(p_1) = 1 - w(p_1)$ and $w_1 = w(p_1)$, with outcomes ranked from worst (outcome 2) to best (outcome 1) and $w(\cdot)$ is the weighting function. We assume $w(\cdot)$ takes the form proposed by Tversky and Kahneman (1992):

$$w(p) = p^{\gamma} \Big/ \left[p^{\gamma} + (1-p)^{\gamma} \right]^{1/\gamma} \quad (9)$$

When γ=1, it implies that $w(p)=p$ and this serves as a formal test of the hypothesis of no probability weighting. In fact Wald tests of the null that γ=1, highly reject the null suggesting that RDU is to be preferred to EUT. Thus, we use the RDU specification hereafter.

The conditional log-likelihood for the time preference task can be written in a similar manner if we write the discounted utility of each option as:

$$PV_A = \frac{M_A^{1-r}}{1-r} \quad \text{and} \quad PV_B = \frac{1}{(1+\delta)^{\tau}} \frac{M_B^{1-r}}{1-r} \qquad (10)$$

and the index of the present values as:

$$\nabla PV = (PV_B - PV_A)/\nu \qquad (11)$$

where ν is a noise parameter for the discount rate tasks[3]. The log-likelihood will then be:

$$\ln L^{DR}(r,\delta,\nu; y, \mathbf{X}) = \sum_i \left(\begin{array}{l} \ln \Phi(\nabla PV) \mid y_i = 1) + (\ln(1-\Phi(\nabla PV)) \mid y_i = -1) \\ + \left(\frac{1}{2} \ln \Phi(\nabla PV) + \frac{1}{2} \ln(1-\Phi(\nabla PV)) \mid y_i = 0 \right) \end{array} \right) \qquad (12)$$

and the joint likelihood will be:

$$\ln L(r,\delta,\mu,\nu; y, \mathbf{X}) = \ln L^{RA}(r,\mu; y, \mathbf{X}) + \ln L^{DR}(r,\delta,\nu; y, \mathbf{X}) \qquad (13)$$

Equation (13) can be maximized using standard numerical methods. We used the routines made available as a supplemental material in Andersen et al. (2008) with appropriate modifications. For a more thorough and pedagogical treatise on maximum likelihood estimation of utility functions, see Appendix F in Harrison and Rutstrom (2008). The statistical specification also takes into account the multiple responses given by the same subject and allows for correlation between responses (clustered standard errors). Standard errors were computed using the delta method.

[3] Contextual utility correction does not need to be applied for these choices since these are over deterministic outcomes.

2.5.2 Calculating the Penalty in Dollars and Overall Liking for Variables not JAR

To elicit the effects of an attribute not JAR on WTP and overall liking, two partial least squares regression models (PLSR) were used on data elicited from treatments groups who tasted the product (Taste and InfoTaste). For each participant, WTP was averaged from rounds 1 and 2. All PLSR models contained JAR variables converted to continuous variables, as developed by (Xiong and Meullenet, 2006). Conversion to *too little* and *too much* dummy variables is necessary because the middle category (just-about-right) of the 5-point JAR scale is the ideal response. In contrast, the ideal category of the 9-point hedonic scale is the highest category (like extremely). In the conversion process, responses valued 4 and 5 on the *too much* side of the JAR attribute are changed to 1 and 2 respectively. All other responses become 0 for the *too much* dummy variable. For the *too little* dummy variable, JAR responses valued at 1 and 2 are converted to -2 and -1 respectively, and all others become 0.

RESULTS AND DISCUSSION

The average participant was younger than 35 years old, college-educated, and married or had a partner (Table 1). Average WTP for the juice blend was $3.45, and average OL was 7.42, which indicates general consumer acceptance.

3.1 LSA on Agreement with Health-Oriented Statements

Overall, consumers disagreed that juice blends were unnatural and that they preferred products made from juice concentrate. Prior to the WTP valuation task, mechanism participants were informed of the optimization/development process the juice blend underwent. As part of the optimization process, consumers evaluated the sensory properties of 7 juice blends and received information about the antioxidant content of juices. Based on the resulting overall liking scores, the blend used in the valuation task was created. Consumers may have viewed juice blend development as positive and natural because of the consumer involvement discussed in this study. Additionally, they may have viewed juice concentrate negatively because of the additional processing this product undergoes. Consumers did not express preference for juice blends over individual juices, which could have been due to consumption habits. Only 30% (n=68) of consumers reported blends as the most frequently consumed fruit juice type of their household.

Consumers were more likely to agree that antioxidants were beneficial to health rather than agree that nutraceuticals can have a noticeable and positive impact on health, which could be due to higher familiarity with the term "antioxidant" than "nutraceutical."

Consumers who indicated they were willing to pay more for healthier juices had preferences for products described as "pure", "natural", "rich in Vitamin C", and "100% juice." Previously, information including "100% pure", "not made from concentrate", "natural", and "not made from concentrate" was shown to increase expected liking of passion fruit juice (Deliza, MacFie, and Hedderley, 2003). External information on champagne labels was shown to have a greater influence than sensory characteristics on overall liking and WTP (Lange, Martin, Chabanet, Combris, and Issanchou, 2002). Additionally, consumers were shown to be willing to pay a premium for "natural" pear juice (Gracia, Lopez, and Virue, 2011). Label information may serve as a cue to consumers that the product is high quality and has pleasing sensory properties.

Sensitivity to sugar as a sweetener is associated with sensitivity to high fructose corn syrup (HFCS) as a sweetener, although there is not strong agreement that HFCS is a less desirable sweetener than table sugar. Consumers who seek products that are natural may be especially suspect of added sweeteners due to the growing presence of added sweeteners in a wide variety of products (Duffey and Popkin, 2008).

3.2 Correlations between Average Non-hypothetical WTP and Agreement with Health-Oriented Statements

Correlations between average WTP and agreement with health-oriented statements profiled each treatment group (Table 2). For Info, agreement that antioxidants are beneficial was significantly correlated to average WTP (r=0.34). Perhaps this group put more cognitive effort into the antioxidant information because this is the only information the Info group received. Additionally, average WTP for Info was positively correlated to preference for juice blends over individual juices (r=0.26) and negatively correlated to preference for juices made from concentrate (r=-0.24). Since consumers were informed that the optimization process included sensory and antioxidant considerations, perhaps this group associated blends with higher antioxidant levels. Additionally, these consumers may perceive that the juice concentration process has a negative effect on sensory attributes perhaps due to the additional processing of the concentration step. The attributes of reconstituted grape juice from concentrate were of lower intensity than the attributes of pasteurized or sugar-sweetened grape juices (Branco Pontes, Santiago, Szabo, Toledo, and Boiago Gollucke, 2010). Internal preference mapping showed that concentrated orange juice was less associated with consumer hedonic vectors than juices from other stages of processing (Janzantti, Machado, and Monteiro, 2011).

The InfoTaste treatment group's average WTP was correlated to agreement that HFCS is less desirable than sugar (r=0.27) and to preference for juice made from concentrate (r=0.25). During the experiment, consumers were not informed about whether the product was made from juice concentrate or whether it contained added sweetener. Perhaps these considerations were more important than the antioxidant information for individuals in the InfoTaste treatment, which could explain why WTP was not significantly correlated to agreement that antioxidants are beneficial. Preference for juice made from concentrate is not predicted by previous studies showing undesirable consequences to sensory attributes from the concentration process (Branco Pontes, Santiago, Szabo, Toledo, and Boiago Gollucke, 2010; Janzantti, Machado, and Monteiro, 2011). Possibly, consumers associated the concentration process with added safety due to the additional processing, or they could have associated juice concentrate with more concentrated flavors.

Average WTP for the control group was negatively correlated to the statement that juice blends were unnatural (r=-0.39), positively correlated to preference for products made from juice concentrate (r=0.29), and positively correlated to WTP more for more expensive, healthier fruit juices (r=0.23). Without the influence of the antioxidant information or sensory evaluation, consumers may have invested more cognitive effort in the explanation of the product optimization, which could have piqued their interest in healthy juice blends.

3.3 WTP Regression Modeling

Random effects regression was used due to the panel nature of the data (i.e., not all observations were independent because of multiple bidding rounds) (Table 3). Censored regression techniques such as tobit regression were unnecessary in this case because of the low frequency of zero bidders.

Overall liking scores of 7 or above were significant and positive predictors of WTP; WTP increased as scores increased. Overall liking in this model represents consumer acceptance based on the information given to a particular treatment group. For Taste and InfoTaste groups, this information included the sensory evaluation. For Info and Control groups, this information included the description of the optimization process, their perception of the sensory properties, and antioxidant information (for the Info group only). Overall liking scores have previously been shown to be significant predictors of willingness-to-pay (Kukowski, Maddock, Wulf, Fausti, and Taylor, 2005; Stefani, Romano, and Cavicchi, 2006; Umberger, and Feuz, 2004).

The Info treatment had a significant effect on WTP, although Taste and InfoTaste treatments did not. This could be due to the optimization procedure. The juice blend was optimized on overall liking scores of juice blends after consumers were given antioxidant information (post-antioxidant). The composition of the optimized blend prior to receipt of antioxidant information (pre-antioxidant) was 77%Con+3%Pom+20%BlkCh, which differed from the post-antioxidant blend (75%Con+12%Pom+13%BlkCh). Had the juice blend been optimized on pre-antioxidant liking scores, the resulting product would have been developed solely on its sensory properties. Thus, the pre-antioxidant product may have had more just-about-right attributes than the post-antioxidant blend (Section 3.4) and may have elicited higher WTP taste coefficients. The Info treatment group received two pieces of positive information about the product, that it was optimized and that it contained antioxidants. Previously, positive information about an antioxidant-enriched wax coating increased WTP for apples (Markosyan, McCluskey, and Wahl, 2009). Information about bioactive compounds extracted from grape skins increased consumer acceptance for extract-infused tea (Cheng, Bekhit, Sedcole, and Hamid, 2010). The current study reinforces the finding that consumers are willing to pay more for polyphenolic antioxidants.

An interaction effect between the Info treatment and time preference was observed. The direction of the coefficient (-8.87) indicates that higher time discount rates are associated with lower WTP within the Info group. In other words, individuals in the Info treatment with less future orientation were generally willing to pay less than those with higher future orientation in the Info treatment. Individuals with less future orientation may not be as protective of their health as those with more future orientation and thus are willing to pay less for health-protective products. While the associations between time discount rates and WTP have been studied previously (Bond, Cullen, and Larson, 2009; Johannesson, and Johansson, 1996; Johannesson, and Johansson, 1997; Sunstein, 2004), the effect of time preference on WTP for nutraceuticals has not been examined.

Risk preference was not a significant predictor of WTP. Although one might expect risk-averse individuals to be willing to pay more for health-protective products, the findings in the current study could be due to the psychological framing of food and drink consumption. Consumers generally consider eating a positive experience (Desmet, and Schifferstein, 2008; King, and Meiselman, 2010). Perhaps considering the risks associated with chronic disease and the aging process detracts from this positive experience, which may discourage consumers from putting high cognitive effort into evaluating risk despite the non-hypothetical nature of the risk preference task.

Home inventory was a significant covariate in the random effects model. Households that had at least 14 days worth of juice or more had lower WTP than households with less juice. Some consumers may have already completed their shopping for the week or may not have had storage available for the juice. Previously, some individuals identified these reasons as factors in their decision to bid 0 for beef (Umberger and Feuz, 2004).

Demographic variables such as income and gender did not significantly affect WTP in the current valuation task, which was shown in some but not all previous valuations for food products to significantly influence WTP (for example, (Bernard and Bernard, 2009; Lange, Martin, Chabanet, Combris, and Issanchou, 2002; Umberger, and Feuz, 2004)). Typically, attitudinal variables are stronger predictors of WTP than demographics, which was the case in the current study.

3.4 Penalty in Dollars and Overall Liking for Variables not JAR

PLSR was used to ascertain the effects of variables not JAR on WTP and overall liking (Table 4). Although the strategy proposed by Xiong and Meullenet (2006) has been applied to models with overall liking and JAR attributes and also to models with overall liking and ideal profiles, this was the first application of regressing JAR dummy variables on WTP (Worch, Dooley, Meullenet, and Punter, 2010; Xiong, and Meullenet, 2006). The Taste and InfoTaste treatments in the current study do not significantly affect WTP when covariates are controlled (Section 3.3), which provides justification for PLSR analysis. Patterns were similar for WTP and overall liking when treatment groups were combined. Reductions in overall liking and WTP occurred because of too little sweetness, too much black cherry flavor, and too much bitterness. Reductions in overall liking also occurred because of too much sourness.

Coefficients indicated the magnitude of the effect on the response variable. For example, the 1.16 *not sweet enough* coefficient for combined groups' overall liking indicated that for every unit of increasing sweetness over the *too little* region (1 to 3), overall liking increased by 1.16. For the same group and attribute, WTP increased $0.25 for every unit increase in sweetness over the *too little* region. For InfoTaste+Taste, overall liking decreased 0.67, and WTP decreased $0.20 over the *too much* region (3 to 5) of black cherry flavor. Finally, for every unit of too much bitterness, overall liking decreased 0.48 and WTP decreased $0.29.

Patterns for InfoTaste+Taste, InfoTaste, and Taste treatment groups varied slightly for both WTP and overall liking. Concerning WTP, three attribute sets were significant in

InfoTaste+Taste, two in InfoTaste, and 0 in Taste. For overall liking, four attribute sets were significant in InfoTaste+Taste, three in InfoTaste, and two in Taste. The discrepancies could be a matter of statistical power. Student's t-test analysis did not show differences between treatment groups for any of the JAR dummy variables. Increasing statistical power by combining similar groups could have more easily produced variable significance.

The number of attributes not JAR could be a result of the sensory optimization procedure. Since post-antioxidant-information overall liking scores were used, the model was influenced by more than sensory properties. The pre-antioxidant-information optimized blend differed from the post-antioxidant-information blend primarily by having a higher black cherry percentage and lower pomegranate percentage. Pomegranate juice was perceived as less sweet and bitterer than black cherry juice (unpublished observations). The higher percentage of pomegranate juice in the post-antioxidant-information blend most likely contributed to the findings for variables not JAR.

Calculating the penalty in dollars instead of overall liking has implications for the product development process. WTP is measured in a monetary, globally understood unit, whereas the concept of overall liking is more abstract. Other authors have observed higher discrimination with bids than with hedonic scores (Lange, Martin, Chabanet, Combris, and Issanchou, 2002). Higher discrimination levels are expected because participants conceptualize their own WTP, whereas overall liking is typically measured in a provided, categorical scale. With an optimized product such as the juice blend, most consumers will only use the top-half of the scale, which further reduces the discriminatory power of the scale. Lange *et al.* (2002) also points out that WTPs of 0 clearly indicate that the participant has no intention of purchasing the product, while low overall liking scores are not clearly related to purchase intent. Moreover, the method proposed in the current study suggests that some variables important to overall liking are not important to WTP; thus, using WTP as the response variable may more easily identify the most important variables.

CONCLUSIONS

Information about antioxidants associated with a nutraceutical-rich juice blend increased WTP, which reinforces previous work showing that consumers respond positively to antioxidant information. When given information about antioxidants, individuals with less future orientation (i.e., higher time discount rates) are willing to pay less than those with more future orientation. Hence, functional benefit information could be incorporated in marketing messages that emphasize protecting health throughout the aging process. Moreover, findings imply that novel functional food products could be targeted to those who have lower time discount rates (i.e., those who are more future-oriented).

The method utilized in this study to identify variables not “optimal” could potentially provide more concrete direction to product developers than traditional penalty analysis because monetary units are less abstract than overall liking. However, the method should be validated with a wider range of products than was tested here.

REFERENCES

Andersen, S., Harrison, G. W., Lau, M. I., and Rutstrom, E. E. (2008) Eliciting risk and time preferences. *Econometrica, 76* (3), 583-618.

Bernard, J. C., & Bernard, D. J. (2009) What Is It About Organic Milk? An Experimental Analysis. *American Journal of Agricultural Economics, 91* (3), 826-836.

Bond, C. A., Cullen, K. G., and Larson, D. M. (2009) Joint estimation of discount rates and willingness to pay for public goods. *Ecological Economics, 68* (11), 2751-2759.

Branco Pontes, P. R., Santiago, S. S., Szabo, T. N., Toledo, L. P., and Boiago Gollucke, A. P. (2010) Sensory attributes and acceptance of commercial grape juices. *Ciencia E Tecnologia De Alimentos, 30* (2), 313-318.

Cheng, V. J., Bekhit, A. E. A., Sedcole, R., and Hamid, N. (2010) The Impact of Grape Skin Bioactive Functionality Information on the Acceptability of Tea Infusions Made from Wine By-Products. *Journal of Food Science, 75* (4), S167-S172.

Coller, M., & Williams, M. B. (1999) Eliciting Individual Discount Rates. *Experimental Economics, 2* (2), 107-127.

Deliza, R., MacFie, H., and Hedderley, D. (2003) Use of computer-generated images and conjoint analysis to investigate sensory expectations. *Journal of Sensory Studies, 18* (6), 465-486.

Desmet, P. M. A., & Schifferstein, H. N. J. (2008) Sources of positive and negative emotions in food experience. *Appetite, 50* (2-3), 290-301.

Dokoupil, T. (2008) A Drink's Purple Rain.

Dooley, L., Threlfall, R. T., and Meullenet, J. F. (2012) Optimization of blended wine quality through maximization of consumer liking. *Food Quality and Preference, 24* (1), 40-47.

Duffey, K. J., & Popkin, B. M. (2008) High-fructose corn syrup: is this what's for dinner? *American Journal of Clinical Nutrition, 88* (6), 1722S-1732S.

Frederick, S., Loewenstein, G., and O'Donoghue, T. (2002) Time discounting and time preference: A critical review. *Journal of Economic Literature, 40* (2), 351-401.

Goldberg, I., Roosen, J., and Nayga, R. M., Jr. (2009) Parental Response to Health Risk Information: Experimental Results on Willingness-To-Pay for Safer Infant Milk Formula. *Health Economics, 18* (5), 503-518.

Gracia, A., Lopez, B., and Virue, S. (2011) Willingness to pay for natural juice: a choice experiment approach. *Itea-Informacion Tecnica Economica Agraria, 107* (1), 21-32.

Guo, C., Wei, J., Yang, J., Xu, J., Pang, W., and Jiang, Y. (2008) Pomegranate juice is potentially better than apple juice in improving antioxidant function in elderly subjects. *Nutrition Research*, *28* (2), 72-77.

Harrison, G. W., & Rutstrom, E. E. (2008). Risk aversion in the laboratory In J. C. Cox and G. W. Harrison, *Research in Experimental Economics Vol 12: Risk Aversion in Experiments,* (pp. 41-196). Bingley, UK: Emerald Group Publishing Limited.

Harrison, G. W., Lau, M. I., and Williams, M. B. (2002) Estimating Individual Discount Rates in Denmark: A Field Experiment. *The American Economic Review, 92* (5), pp. 1606-1617.

Holt, C. A., & Laury, S. K. (2002) Risk Aversion and Incentive Effects. *American Economic Review, 92* (5), 1644-1655.

Janzantti, N. S., Machado, T. V., and Monteiro, M. (2011) Sensory Acceptance of Juice from Fcoj Processing Steps. *Journal of Sensory Studies, 26* (5), 322-330.

Johannesson, M., & Johansson, P. (1997) Quality of life and the WTP for an increased life expectancy at an advanced age RID E-9680-2011. *Journal of Public Economics, 65* (2), 219-228.

Johannesson, M., & Johansson, P. (1996) To be, or not to be, that is the question: An empirical study of the WTP for an increased life expectancy at an advanced age RID E-9680-2011. *Journal of Risk and Uncertainty, 13* (2), 163-174.

Kim, D. O., Heo, H. J., Kim, Y. J., Yang, H. S., and Lee, C. Y. (2005) Sweet and sour cherry phenolics and their protective effects on neuronal cells. *Journal of Agricultural and Food Chemistry, 53* (26), 9921-9927.

King, S. C., & Meiselman, H. L. (2010) Development of a method to measure consumer emotions associated with foods. *Food Quality and Preference, 21* (2), 168-177.

Krikorian, R., Nash, T. A., Shidler, M. D., Shukitt-Hale, B., and Joseph, J. A. (2010) Concord grape juice supplementation improves memory function in older adults with mild cognitive impairment. *British Journal of Nutrition, 103* (5), 730-734.

Kukowski, A., Maddock, R., Wulf, D., Fausti, S., and Taylor, G. (2005) Evaluating consumer acceptability and willingness to pay for various beef chuck muscles. *Journal of Animal Science, 83* (11), 2605-2610.

Lange, C., Martin, C., Chabanet, C., Combris, P., and Issanchou, S. (2002) Impact of the information provided to consumers on their willingness to pay for Champagne: comparison with hedonic scores. *Food Quality and Preference, 13* (7-8), 597-608.

Lansky, E. P., Harrison, G., Froom, P., and Jiang, W. G. (2005) Pomegranate (Punica granatum) pure chemicals show possible synergistic inhibition of human PC-3 prostate cancer cell invasion across Matrigel (TM). *Investigational New Drugs, 23* (2), 121-122.

Lansky, E. P., Jiang, W. G., Mo, H. B., Bravo, L., Froom, P., Yu, W. P., Harris, N. M., Neeman, I., and Campbell, M. J. (2005) Possible synergistic prostate cancer suppression by anatomically discrete pomegranate fractions. *Investigational New Drugs, 23* (1), 11-20.

Lawless, L. J. R., Nayga, R. M., Akaichi, F., Meullenet, J. F., Threlfall, R. T., and Howard, L. R. (2012, in press) Willingness-to-pay for Nutraceutical-rich Juice Blend. *Journal of Sensory Studies,*

Lund, C. M., Jaeger, S. R., Amos, R. L., Brookfield, P., and Harker, F. R. (2006) Tradeoffs between emotional and sensory perceptions of freshness influence the price consumers will pay for apples: Results from an experimental market. *Postharvest Biology and Technology, 41* (2), 172-180.

Lusk, J., Feldkamp, T., and Schroeder, T. (2004) Experimental auction procedure: Impact on valuation of quality differentiated goods. *American Journal of Agricultural Economics, 86* (2), 389-405.

Markosyan, A., McCluskey, J. J., and Wahl, T. I. (2009) Consumer Response to Information about a Functional Food Product: Apples Enriched with Antioxidants. *Canadian Journal of Agricultural Economics-Revue Canadienne D Agroeconomie, 57* (3), 325-341.

Maynard, L. J., & Franklin, S. T. (2003) Functional foods as a value-added strategy: The commercial potential of "cancer-fighting" dairy products. *Review of Agricultural Economics, 25* (2), 316-331.

Meullenet, J. -., Xiong, R., and Findlay, C. J. (2007) *Multivariate and probabilistic analyses of sensory science problems.* U.S.A.: IFT Press and Blackwell Publishing.

Mundy, A. (2010) Regulator Sues Pomegranate Juice Maker. *Wall Street Journal,* http://online.wsj.com/article/SB10001424052748704654004575517871757238034.html.

Munoz-Espada, A. C., Wood, K. V., Bordelon, B., and Watkins, B. A. (2004) Anthocyanin quantification and radical scavenging capacity of Concord, Norton, and Marechal Foch grapes and wines. *Journal of Agricultural and Food Chemistry, 52* (22), 6779-6786.

Nayga, R. M., Jr. (2008) Nutrition, obesity and health: policies and economic research challenges. *European Review of Agricultural Economics, 35* (3), 281-302.

Noussair, C., Robin, S., and Ruffieux, B. (2004) Revealing consumers' willingness-to-pay: A comparison of the BDM mechanism and the Vickrey auction. *Journal of Economic Psychology, 25* (6), 725-741.

Onwezen, M. C., & Bartels, J. (2011) Which perceived characteristics make product innovations appealing to the consumer? A study on the acceptance of fruit innovations using cross-cultural consumer segmentation. *Appetite, 57* (1), 50-58.

Pacheco-Palencia, L. A., Noratto, G., Hingorani, L., Talcott, S. T., and Mertens-Talcott, S. U. (2008) Protective effects of standardized pomegranate (Punica granatum L.) polyphenolic extract in ultraviolet-irradiated human skin fibroblasts. *Journal of Agricultural and Food Chemistry, 56* (18), 8434-8441.

Peng, Y., West, G. E., and Wang, C. (2006) Consumer attitudes and acceptance of CLA-enriched dairy products. *Canadian Journal of Agricultural Economics-Revue Canadienne D Agroeconomie, 54* (4), 663-684.

Quiggin, J. (1982) A Theory of Anticipated Utility. *Journal of Economic Behavior & Organization, 3* (4), 323-343.

Rowe, C. A., Nantz, M. P., Nieves, C., Jr., West, R. L., and Percival, S. S. (2011) Regular Consumption of Concord Grape Juice Benefits Human Immunity. *Journal of Medicinal Food, 14* (1-2), 69-78.

Seeram, N. P., Aviram, M., Zhang, Y., Henning, S. M., Feng, L., Dreher, M., and Heber, D. (2008) Comparison of antioxidant potency of commonly consumed Polyphenol-Rich beverages in the united states. *Journal of Agricultural and Food Chemistry, 56* (4), 1415-1422.

Shahrabani, S., Benzion, U., and Shavit, T. (2008) WTP and WTA in competitive and non-competitive environments. *Judgment and Decision Making Journal, 3* (2), 153-161.

Stefani, G., Romano, D., and Cavicchi, A. (2006) Consumer expectations, liking and willingness to pay for specialty foods: Do sensory characteristics tell the whole story? *Food Quality and Preference, 17* (1-2), 53-62.

Stephens, G. (2008) Baby Boomers and the Role of Nutraceutical Ingredients. *Cereal Foods World, 53* (6), 306-307.

Sunstein, C. R. (2004) Lives, life-years, and willingness to pay. *Columbia Law Review, 104* (1), 205-252.

Szakaly, Z., Szente, V., Koever, G., Polereczki, Z., and Szigeti, O. (2012) The influence of lifestyle on health behavior and preference for functional foods. *Appetite, 58* (1), 406-413.

Tversky, A., & Kahneman, D. (1992) Advances in Prospect-Theory - Cumulative Representation of Uncertainty. *Journal of Risk and Uncertainty, 5* (4), 297-323.

Umberger, W., & Feuz, D. (2004) The usefulness of experimental auctions in determining consumers' willingness-to-pay for quality-differentiated products. *Review of Agricultural Economics, 26* (2), 170-185.

Usenik, V., Fabcic, J., and Stampar, F. (2008) Sugars, organic acids, phenolic composition and antioxidant activity of sweet cherry (Prunus avium L.). *Food Chemistry, 107* (1), 185-192.

West, G., Gendron, C., Larue, B., and Lambert, R. (2002) Consumers' valuation of functional properties of foods: Results from a Canada-wide survey. *Canadian Journal of Agricultural Economics-Revue Canadienne D Agroeconomie*, *50* (4), 541-558.

Wilcox, N. T. (2011) 'Stochastically More Risk Averse': A Contextual Theory of Stochastic Discrete Choice under Risk. *Journal of Econometrics*, *162* (1), 89-104.

Worch, T., Dooley, L., Meullenet, J., and Punter, P. H. (2010) Comparison of PLS dummy variables and Fishbone method to determine optimal product characteristics from ideal profiles. *Food Quality and Preference*, *21* (8), 1077-1087.

Xiong, R., & Meullenet, J. (2006) A PLS dummy variable approach to assess the impact of jar attributes on liking. *Food Quality and Preference, 17* (3-4), 188-198.

Xue, H., Mainville, D., You, W., and Nayga, R. M., Jr. (2010) Consumer preferences and willingness to pay for grass-fed beef: Empirical evidence from in-store experiments. *Food Quality and Preference, 21* (7), 857-866.

TABLE 1. DEMOGRAPHIC SUMMARY[a]

Gender					
	Female	Male			
Control	36	19			
Info	37	16			
InfoTaste	41	22			
Taste	39	18			
Total	153	75			
Domestic Status					
	Married/Partner	Single	Other		
Control	32	19	4		
Info	35	17	1		
InfoTaste	38	25	0		
Taste	28	29	0		
Total	133	90	5		
Age					
	18-35	35-54	55+		
Control	18	24	13		
Info	19	24	10		
InfoTaste	29	22	12		
Taste	29	18	10		
Total	95	88	45		
Education[b]					
	High School	Some College	2-year College Degree	4-year College Degree	Graduate Degree
Control	10	10	6	21	8
Info	10	18	3	9	13
InfoTaste	7	17	2	20	17
Taste	3	20	3	17	14
Total	30	65	14	67	52

[a]Control is the treatment group who did not receive antioxidant information and did not complete the sensory evaluation, Info is the treatment group who received antioxidant information, Taste is the treatment group who completed the sensory evaluation, and InfoTaste is the treatment group who received antioxidant information and completed the sensory evaluation.
[b]Highest level of education completed

FIG. 1. AUCTION FLOW DIAGRAM

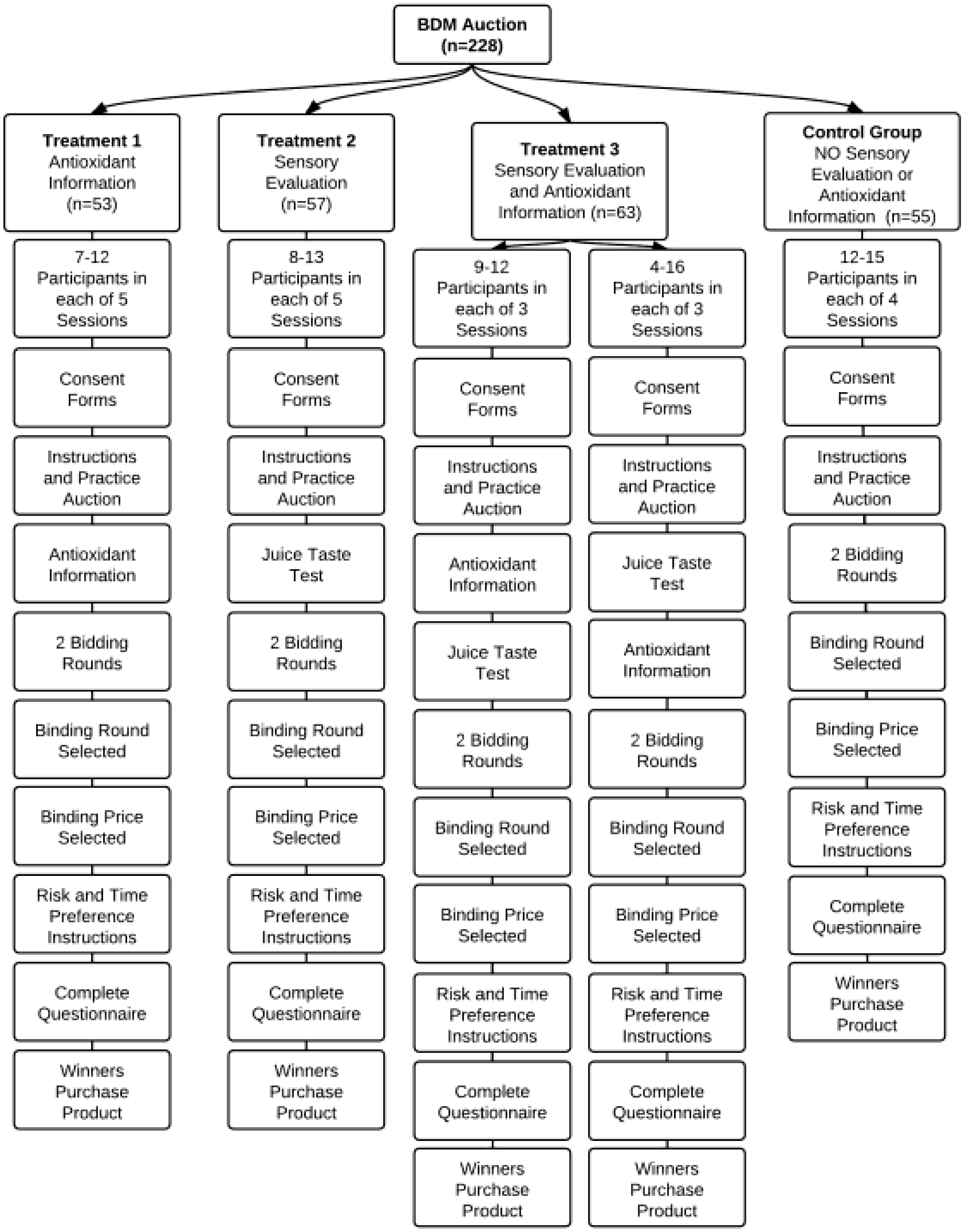
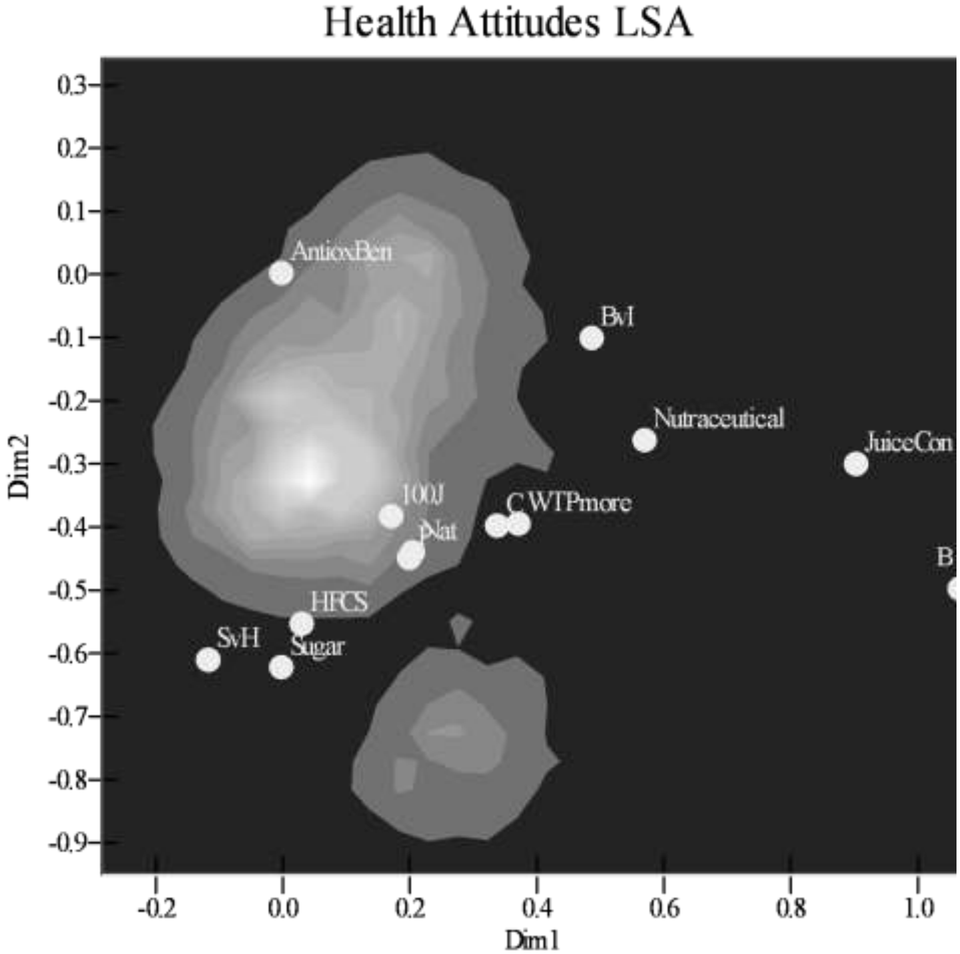


FIG. 2. LANDSCAPE SEGMENTATION ANALYSIS ON AGREEMENT TO HEALTH-ORIENTED STATEMENTS



[a]Abbreviations: Antioxidants are beneficial to my health. (AntioxBen); I prefer juice blends over individual juices. (BvI); Consuming nutraceuticals can have a noticeable positive impact on my health. (Nutraceutical); I am willing to pay more for more expensive fruit juices that are healthier for me. (WTP more); I prefer fruit juice products that claim to be pure. (P); I prefer fruit juice products that claim to be 100% juice. (100J); I prefer fruit juice products that claim to be natural. (Nat); I prefer fruit juice products that claim to be rich in Vitamin C. (C); I prefer fruit juice products that are made from juice concentrate. (JuiceCon); Juice blends are unnatural. (B); I mind if fruit juices are sweetened with sugar. (Sugar); I mind if fruit juices are sweetened with high fructose corn syrup. (HFCS); In sweetened fruit juices, high fructose corn syrup is a less desirable sweetener than table sugar. (SvH)

TABLE 2. CORRELATIONS BETWEEN AVERAGE WILLINGNESS-TO-PAY (WTP) AND HEALTH-ORIENTED STATEMENTS[a,b,c]

Treatment	by Variable	Correlation	P-Value
Control	Antioxidants are beneficial to my health.	0.19	0.1651
Info	Antioxidants are beneficial to my health.	0.34	0.0141
InfoTaste	Antioxidants are beneficial to my health.	0.14	0.2576
Taste	Antioxidants are beneficial to my health.	0.15	0.2624
Control	I mind if fruit juices are sweetened with sugar.	0.12	0.3876
Info	I mind if fruit juices are sweetened with sugar.	0.24	0.0846
InfoTaste	I mind if fruit juices are sweetened with sugar.	0.03	0.8087
Taste	I mind if fruit juices are sweetened with sugar.	0.06	0.6384
Control	I mind if fruit juices are sweetened with high fructose corn syrup.	0.15	0.2831
Info	I mind if fruit juices are sweetened with high fructose corn syrup.	0.20	0.1477
InfoTaste	I mind if fruit juices are sweetened with high fructose corn syrup.	0.11	0.3984
Taste	I mind if fruit juices are sweetened with high fructose corn syrup.	0.07	0.6122
Control	In sweetened fruit juices, high fructose corn syrup is a less desirable sweetener than table sugar.	0.16	0.2333
Info	In sweetened fruit juices, high fructose corn syrup is a less desirable sweetener than table sugar.	0.14	0.3226
InfoTaste	In sweetened fruit juices, high fructose corn syrup is a less desirable sweetener than table sugar.	0.27	0.0306
Taste	In sweetened fruit juices, high fructose corn syrup is a less desirable sweetener than table sugar.	-0.13	0.3228
Control	I prefer fruit juice products that claim to be 100% juice.	0.09	0.5011
Info	I prefer fruit juice products that claim to be 100% juice.	0.05	0.7065
InfoTaste	I prefer fruit juice products that claim to be 100% juice.	0.10	0.4465
Taste	I prefer fruit juice products that claim to be 100% juice.	0.10	0.4508
Control	I prefer juice blends over individual juices.	0.10	0.46
Info	I prefer juice blends over individual juices.	0.26	0.0631
InfoTaste	I prefer juice blends over individual juices.	-0.02	0.8979
Taste	I prefer juice blends over individual juices.	0.11	0.3961
Control	I prefer fruit juice products that claim to be pure.	0.12	0.3647
Info	I prefer fruit juice products that claim to be pure.	0.06	0.6487
InfoTaste	I prefer fruit juice products that claim to be pure.	0.01	0.9418
Taste	I prefer fruit juice products that claim to be pure.	0.06	0.6718

Control	I prefer fruit juice products that claim to be natural.	-0.06	0.6767
Info	I prefer fruit juice products that claim to be natural.	0.03	0.8548
InfoTaste	I prefer fruit juice products that claim to be natural.	0.05	0.6846
Taste	I prefer fruit juice products that claim to be natural.	-0.02	0.897
Control	I prefer fruit juice products that claim to be rich in Vitamin C.	-0.12	0.3647
Info	I prefer fruit juice products that claim to be rich in Vitamin C.	-0.06	0.6614
InfoTaste	I prefer fruit juice products that claim to be rich in Vitamin C.	0.10	0.4304
Taste	I prefer fruit juice products that claim to be rich in Vitamin C.	0.02	0.8837
Control	Juice blends are unnatural.	-0.39	0.0033
Info	Juice blends are unnatural.	-0.17	0.2146
InfoTaste	Juice blends are unnatural.	-0.12	0.348
Taste	Juice blends are unnatural.	0.03	0.8383
Control	I prefer fruit juice products that are made from juice concentrate.	0.29	0.0338
Info	I prefer fruit juice products that are made from juice concentrate.	-0.24	0.0898
InfoTaste	I prefer fruit juice products that are made from juice concentrate.	0.25	0.0476
Taste	I prefer fruit juice products that are made from juice concentrate.	0.16	0.2397
Control	Consuming nutraceuticals can have a noticeable positive impact on my health.	0.28	0.0382
Info	Consuming nutraceuticals can have a noticeable positive impact on my health.	0.12	0.3771
InfoTaste	Consuming nutraceuticals can have a noticeable positive impact on my health.	0.01	0.9109
Taste	Consuming nutraceuticals can have a noticeable positive impact on my health.	0.00	0.978
Control	I am willing to pay more for more expensive fruit juices that are healthier for me.	0.23	0.0889
Info	I am willing to pay more for more expensive fruit juices that are healthier for me.	0.15	0.2903
InfoTaste	I am willing to pay more for more expensive fruit juices that are healthier for me.	0.17	0.1846
Taste	I am willing to pay more for more expensive fruit juices that are healthier for me.	0.01	0.9687

[a]Likert and WTP observations are Control (n=55), Info (n=53), Taste (n=57), InfoTaste(n=63), where Control is the treatment group who did not receive antioxidant information and did not complete the sensory evaluation, Info is the treatment group who received antioxidant information, Taste is the treatment group who completed the sensory evaluation, and InfoTaste is the treatment group who received antioxidant information and completed the sensory evaluation.

[b]Pairwise correlations performed between agreement to health statements and WTP averaged from bidding rounds 1 and 2.

[c]Shading indicates significance of the correlations at p<0.10

TABLE 3. RANDOM EFFECTS REGRESSION MODELING ON WILLINGNESS-TO-PAY FOR JUICE[a,b]

		Coefficient	Standard Error	Z-value	P>lzl
Overall Liking	3	2.10	1.91	1.10	0.270
	4	0.89	1.92	0.46	0.642
	5	2.42	1.76	1.38	0.168
	6	2.06	1.69	1.22	0.224
	7	2.99	1.66	1.80	0.071
	8	3.17	1.65	1.92	0.054
	9	4.30	1.69	2.55	0.011
Treatment	Info	3.58	1.78	2.01	0.045
	InfoTaste	0.66	1.78	0.37	0.712
	Taste	0.18	1.76	0.10	0.918
Risk		2.15	1.55	1.39	0.165
Risk*Treatment	Info	-3.68	2.43	-1.52	0.129
	InfoTaste	-1.91	2.38	0.80	0.424
	Taste	0.41	2.46	0.17	0.868
Time		4.67	3.29	1.42	0.155
Time*Treatment	Info	-8.87	5.15	-1.72	0.085
	InfoTaste	-2.39	5.14	-0.46	0.642
	Taste	-0.44	5.05	-0.09	0.931
Round		0.05	0.03	1.59	0.113
Income	20-29999	-0.27	0.57	-0.47	0.636
	30-39999	-0.04	0.58	-0.07	0.942
	40-49999	-0.37	0.64	-0.57	0.569
	50-59999	-0.34	0.62	-0.56	0.579
	60-69999	-0.21	0.64	-0.33	0.741
	70-79999	-0.29	0.59	-0.49	0.625
	80-89999	1.01	0.68	1.49	0.137
	90-99999	-1.11	0.84	-1.32	0.186
	More100K	0.17	0.70	0.25	0.802
	Under 15K	-0.82	0.56	-1.46	0.145
Gender[c]		0.43	0.33	1.28	0.200
Home Inventory (>14 days)		-0.98	0.39	-2.52	0.012

[a]Treatment group 1 (Info) received the following information about the juice blend: *This juice blend is rich in polyphenolic antioxidants, which are thought to support health.* Treatment group 2 (Taste) evaluated sensory attributes of the juice blend. Treatment group 3 (InfoTaste) evaluated the sensory properties of the juice blend and received the antioxidant information. The control group (Control) neither tasted nor received information about the juice blend.
[b]Shading indicates significance of the effect at p<0.10
[c]Gender Dummy (1=male)

TABLE 4. PARTIAL LEAST SQUARES REGRESSION MODELING ON WILLINGNESS-TO-PAY AND OVERALL LIKING FOR CONVERTED JUST-ABOUT-RIGHT VARIABLES[a,b,c]

		Intercept	Too Sweet	Not Sweet Enough	Too Sour	Not Sour Enough	Too Much Pom Fl	Not Enough Pom Fl	Too Much Concord Fl	Not Enough Concord Fl	Too Much BlkCh Fl	Not Enough BlkCh Fl	Too Ast	Not Ast Enough	Too Bitter	Not Bitter Enough
InfoTaste+Taste	WTP	$3.56	0.03	0.25	-0.09	-0.03	-0.03	0.08	0.10	0.11	-0.20	-0.06	-0.13	-0.02	-0.29	-0.06
	Overall Liking	8.23	-0.04	1.16	-0.56	0.00	-0.39	0.13	-0.34	0.45	-0.67	0.24	0.10	0.15	-0.48	0.12
InfoTaste	WTP	$3.44	-0.03	0.25	-0.12	-0.06	-0.11	0.00	-0.07	0.16	-0.29	-0.17	-0.18	0.04	-0.23	-0.16
	Overall Liking	7.70	0.06	0.84	-0.59	-0.03	-0.17	-0.06	-0.17	0.28	-0.70	-0.14	-0.17	-0.03	-0.59	0.06
Taste	WTP	$3.66	0.12	0.32	-0.32	-0.05	0.37	0.14	0.25	0.03	-0.31	-0.01	0.17	-0.19	-0.60	-0.07
	Overall Liking	8.33	-0.44	1.15	-0.59	-0.23	-1.51	0.28	-0.05	0.13	-0.01	0.23	0.08	0.88	0.26	-0.37

[a]Abbreviations: Treatment group (n=63) who received antioxidant information and who completed the sensory evaluation (InfoTaste), Treatment group (n=57) who only completed the sensory evaluation (Taste), Pomegranate Flavor (Pom Fl), Concord Flavor (Con Fl), Black Cherry Flavor (BlkCh Fl), Astringency (Ast)

[b]Shading indicates significance of the variable in the PLSR model at $\alpha<0.05$

[c]Student's T-test models with treatment as x-variable and either overall liking, average WTP, or JAR dummy variables as y-variables indicated differences between treatment groups for overall liking only (Infotaste: 7.00, Taste: 7.61)

Appendix 5.1. Time Preference Tasks

Task A: Please choose which option you prefer for each row in the table below (3 months interval):

Option A		Option B		Interest rate
$300 in one month		$304 in 4 months		5%
$300 in one month		$308 in 4 months		10%
$300 in one month		$311 in 4 months		15%
$300 in one month		$315 in 4 months		20%
$300 in one month		$319 in 4 months		25%
$300 in one month		$323 in 4 months		30%
$300 in one month		$326 in 4 months		35%
$300 in one month		$330 in 4 months		40%
$300 in one month		$334 in 4 months		45%
$300 in one month		$338 in 4 months		50%

Task B: Please choose which option you prefer for each row in the table below (6 months interval):

Option A		Option B		Interest rate
$300 in one month		$308 in 7 months		5%
$300 in one month		$315 in 7 months		10%
$300 in one month		$323 in 7 months		15%
$300 in one month		$330 in 7 months		20%
$300 in one month		$338 in 7 months		25%
$300 in one month		$345 in 7 months		30%
$300 in one month		$353 in 7 months		35%
$300 in one month		$360 in 7 months		40%
$300 in one month		$368 in 7 months		45%
$300 in one month		$375 in 7 months		50%

Payoff

To determine winners and payoffs one of the two tasks will be randomly selected as binding.

If **Task 3** is selected as binding, one of the rows will be selected as binding and subject's choice will be realized with 10% chance across all tasks.

If **Task 4** is selected as binding, one of the rows will be selected as binding and subject's choice will be realized with 10% chance across all tasks.

Appendix 5.2. Risk Preference Tasks

Task A: Please choose which option you prefer for each row in the table below:

Option A		Option B	
10% chance of winning $2, 90% of winning $1.60		10% chance of winning $3.85, 90% of winning $0.10	
20% chance of winning $2, 80% of winning $1.60		20% chance of winning $3.85, 80% of winning $0.10	
30% chance of winning $2, 70% of winning $1.60		30% chance of winning $3.85, 70% of winning $0.10	
40% chance of winning $2, 60% of winning $1.60		40% chance of winning $3.85, 60% of winning $0.10	
50% chance of winning $2, 50% of winning $1.60		50% chance of winning $3.85, 50% of winning $0.10	
60% chance of winning $2, 40% of winning $1.60		60% chance of winning $3.85, 40% of winning $0.10	
70% chance of winning $2, 30% of winning $1.60		70% chance of winning $3.85, 30% of winning $0.10	
80% chance of winning $2, 20% of winning $1.60		80% chance of winning $3.85, 20% of winning $0.10	
90% chance of winning $2, 10% of winning $1.60		90% chance of winning $3.85, 10% of winning $0.10	
100% chance of winning $2, 0% of winning $1.60		100% chance of winning $3.85, 0% of winning $0.10	

Task B: Please choose which option you prefer for each row in the table below:

Option A		Option B	
10% chance of winning $20, 90% of winning $16		10% chance of winning $38.50, 90% of winning $1	
20% chance of winning $20, 80% of winning $16		20% chance of winning $38.50, 80% of winning $1	
30% chance of winning $20, 70% of winning $16		30% chance of winning $38.50, 70% of winning $1	
40% chance of winning $20, 60% of winning $16		40% chance of winning $38.50, 60% of winning $1	
50% chance of winning $20, 50% of winning $16		50% chance of winning $38.50, 50% of winning $1	
60% chance of winning $20, 40% of winning $16		60% chance of winning $38.50, 40% of winning $1	
70% chance of winning $20, 30% of winning $16		70% chance of winning $38.50, 30% of winning $1	
80% chance of winning $20, 20% of winning $16		80% chance of winning $38.50, 20% of winning $1	
90% chance of winning $20, 10% of winning $16		90% chance of winning $38.50, 10% of winning $1	
100% chance of winning $20, 0% of winning $16		100% chance of winning $38.50, 0% of winning $1	

Payoff

To determine winners and payoffs one of the two tasks will be randomly selected as binding.

If **Task 1** is selected as binding, one of the rows will be selected as binding and subject's choice will be realized with 10% chance across all tasks.

If **Task 2** is selected as binding, one of the rows will be selected as binding and subject's choice will be realized with 10% chance across all tasks.

CHAPTER 9

Research Conclusions

Mixture optimizations of nutraceutical-rich juice offer opportunities to simultaneously maximize consumer satisfaction and potentially health-promoting phytochemicals. Experimental auctions can be used to identify the value consumers give to the sensory and nutraceutical properties of juice. Understanding the compositional and sensory changes that occur during product storage is an important aspect of product development.

Blackberry, blueberry, and Concord juices were blended according to an ABCD mixture design (3 primary blends, 3 secondary blends, 4 tertiary blends) and analyzed to identify their compositional and sensory properties. According to a trained descriptive panel (n=8), initially, Concord-containing blends were generally sweeter, less bitter, less astringent, and less sour than blackberry- or blueberry-containing blends. Consumers found Concord juice more acceptable than blueberry or blackberry juice due in part to its higher soluble solids content. During storage, the major sensory changes occurred to the color of Concord juice, which turned browner during the 200-day storage period. Anthocyanin content in the juice blends decreased as they were polymerized over time.

Four optimization methods based on the ABCD mixture design (desirability function, ideal point, response surface and intuition) were compared for their ability to produce optimized blends that consumers liked significantly more than the original blending treatments. The desirability solution (13%Blk+87%Con), the ideal point solution (9%Blk+20%Blu+71%Con), and the intuitive solution (34%Blu+66%Con) were liked as much as 100%Con, the most liked blending treatment from the initial consumer study. The optimized solutions had the added benefit of higher anthocyanin and phenolic contents. Future research could test these optimization methods in a wider array of products.

When given comparative nutraceutical information, the majority of consumers were more likely to purchase the products higher in anthocyanins. This suggests that pursuing research that validates the health benefits of anthocyanins and informing consumers of these benefits could have positive results in the marketplace.

The optimized solution with the highest overall liking mean (13%Blk+87%Con) was auctioned in an experimental auction to determine willingness-to-pay (WTP). In general, auction participants accepted the juice blend, which indicates that this product could be successful in the marketplace. Consumers who tasted the product first and then received a hypothetical health statement about potentially health-beneficial antioxidants were willing to pay more for the juice blend than participants who received the hypothetical health statement first and then tasted the juice blend. Results have implications for product adoption and marketing strategies. Generally, consumers repeat purchase only if sensory expectations are met after the initial purchase (Di Monaco *et al.* 2004, Deliza and MacFie 1996). The role of meeting sensory expectations in purchase behavior may be expanded for nutraceutical products because of some consumers' general attitudes about the inferior taste of healthy foods. To overcome this bias, offering low-risk opportunities for consumers to taste nutraceutical products before the first purchase may be necessary for marketplace success.

Improvements to the initial optimization methods in this dissertation were pursued with a combination of choice and mixture designs. A choice design was employed to select the best three-component juice blend of açaí, black cherry (BlkCh), blueberry, Concord grape (Con), cranberry, and pomegranate (Pom) juices, which were previously identified as polyphenolic-rich (Seeram *et al.* 2008). The *black cherry, Concord grape, and pomegranate* blend was chosen as the best to further optimize because it had the highest marginal utility. Generally, as juice blending components, pomegranate and Concord grape increased utility, blueberry and açaí decreased utility, and black cherry and cranberry were mostly utility-neutral. Choices were primarily motivated by antioxidant status of the blending component and overall liking. Choice designs were effective in screening a vast array of products and identifying the products with the most potential.

As part of the development of the *black cherry, Concord grape, and pomegranate* juice blend, optimized blends were calculated with the desirability function on overall liking scores before (77%Con+3%Pom+20%BlkCh) and after (75%Con+12%Pom+13%BlkCh) consumers were given information about the antioxidant content of the sample. After consumers received antioxidant information, the most desirable blend shifted to contain more pomegranate juice, which was highest in antioxidants. Generally, consumer acceptance is driven primarily by sensory qualities, although nutraceutical status can provide consumers additional utility. The advantage of evaluating consumer acceptance after consumers have information about the nutraceutical status and sensory properties of the product is that the ensuing optimization considers the value of the nutraceutical information as measured by consumers, not laboratory instruments.

Evaluating consumer acceptance data for nutraceuticals in conjunction with descriptive and diagnostic (e.g., just-about-right) data provides a more comprehensive understanding of how products should be adjusted to maximize consumer acceptance. Examing diagnostic data for pomegranate juice, black cherry juice, and Concord grape juice revealed that a three-component juice blend (33%BlkCh+33%Con+33%Pom) was better balanced blend than pomegranate or black cherry juice and contained more antioxidants than Concord juice. Thus, juice blending was shown to be an effective way to improve nutraceutical juice.

An experimental auction using the optimized juice blend (75%Con+12%Pom+13%BlkCh) revealed several important findings. Information about antioxidants increased WTP for the juice blend, which reinforces previous work showing consumers respond positively to antioxidant information (Markosyan *et al.* 2009). Less future orientation (i.e., higher time discount rates) in conjunction with antioxidant information negatively impacts WTP, which indicates that individuals with more future orientation are more likely to respond positively to health-oriented information. Functional benefit information could be incorporated in marketing messages that emphasize protecting health throughout the aging process.

Converting each just-about-right attribute to a set of two dummy variables and regressing against WTP provides more concrete direction to product developers than traditional penalty analysis because monetary units are less abstract than overall liking. Future research should focus on validating the method with a wider range of products.

The previous pages of this dissertation offer a number of important contributions to the literature. Among them are improvements to optimization methods that consider nutraceutical and sensory properties, further incorporation of economic concepts (experimental auctions, risk aversion, time preference) to sensory science, and enhancement of diagnostic data analysis.

REFERENCES

DELIZA, R. and MACFIE, H. 1996. The generation of sensory expectation by external cues and its effect on sensory perception and hedonic ratings: A review. J. Sens. Stud. *11*, 103-128, DOI: 10.1111/j.1745-459X.1996.tb00036.x.

DI MONACO, R., CAVELLA, S., DI MARZO, S. and MASI, P. 2004. The effect of expectations generated by brand name on the acceptability of dried semolina pasta. Food. Qual. Prefer. *15*, 429-437, DOI: 10.1016/j.foodqual.2003.07.003.

MARKOSYAN, A., MCCLUSKEY, J.J. and WAHL, T.I. 2009. Consumer Response to Information about a Functional Food Product: Apples Enriched with Antioxidants. Can. J. Agric. Econ. -Rev. Can. Agroecon. *57*, 325-341.

SEERAM, N.P., AVIRAM, M., ZHANG, Y., HENNING, S.M., FENG, L., DREHER, M. and HEBER, D. 2008. Comparison of antioxidant potency of commonly consumed Polyphenol-Rich beverages in the united states. J. Agric. Food Chem. *56*, 1415-1422, DOI: 10.1021/jf073035s.