Domestic apple cultivars

Sensory descriptions and consumer responses

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ACADEMIC DISSERTATION

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Front cover: Word cloud of ideal apple descriptions

"Outside the gate of the outer court there is a large garden of about four acres with a wall all round it. It is full of beautiful trees- pears, pomegranates, and the most delicious apples. There are luscious figs also, and olives in full growth. The fruits never rot nor fail all the year round, neither winter nor summer, for the air is so soft that a new crop ripens before the old has dropped. Pear grows on pear, apple on apple, and fig on fig..."

Homer, The Odyssey (translated by Samuel Butler)

"... food quality is a relative concept that is inappropriate for evaluation by anyone other than the average consumer of that food."

H. Clarke, 1870 (quoted by Cardello 1995).

CONTENTS

ABSTRACT

The present study concentrates on the prospects of domestic apple production and consumption by developing sensory profiles for selected apple cultivars and relating these to consumer responses. Characteristics of the cultivars and changes in these characteristics during storage were studied with generic descriptive analysis (GDA). Repeated liking and choices of apples by Finnish apple consumers were examined and consumers segmented according to their appreciation of apple characteristics. Respondents also described their most favourite apple in their own words. Hedonic ratings and information available during evaluation were used to explain consumers' willingness to pay (WTP) for apples.

A lexicon consisting of 20 attributes and procedure for the analysis of apples with GDA were developed by a trained panel. Profiles were constructed for 15 domestic cultivars. To facilitate communication of the cultivar characteristics to a wider audience, the lexicon was further developed to build simplified profiles with nine attributes. Storage induced sensory changes during prolonged storage of 8 to 17 weeks were defined and quantified with the same method. Major changes were observed during the follow-up period, but the differences in cultivar performance were large. The storage influenced mostly texture, especially juiciness and mealiness, but some cultivars retained their eating quality well and showed promise for extended storability.

The research on repeated choices (n=108) revealed that an apple is chosen based not only on the liking of that cultivar, but also disliking the other options. Individual choice criteria and orientations towards certain kinds of apples play also a role in the choice. Initial liking did not entirely explain liking during repeated choices. Apple eaters were clustered into three consumer segments based on whether they preferred sweet & soft or sour & firm apples, or apples with medium sourness and medium sweetness.

The respondents to an open-ended question regarding their ideal apple (n=122) used over 500 expressions to describe their favourite apple. Of the descriptions, 145 were related to texture, 118 to flavour and 34 to a specific colour. Freshness, cleanness, healthiness, beauty and the origin of apples were mentioned over 100 times, suggesting that the mental image and conception of the product is vital.

The effect of individual and cumulating information on hedonic ratings, and further on WTP was studied with experimental auction procedure (n=118). The frequent eaters of domestic apples were more willing to pay a higher price for them than the less frequent eaters. The mean price premium for domestic apples was 2.36 euro/kg, while the frequent eaters were willing to pay over 0.50 euro/kg higher prices. When the ratings of pleasantness and WTP were based on the appearance of the apples only, differences in the ratings were rather small between the cultivars, while especially tasting revealed clear differences. Pleasantness explained about half of the variation in WTP, but differences between the cultivars were substantial.

In the thesis a method was developed to describe the sensory properties of mature and stored domestic apples for the first time. The typical characteristics of several cultivars changed considerably in the course of storage, while some cultivars showed a promising capacity to withstand sensory changes for quite a long period of storage. Thus, not only the cultivar but also the storage time defines the sensory properties of an apple. The results of the consumer studies indicate that hedonic ratings, individual apple preferences, use frequency and cumulating information affect sensory ratings. Hence, there are markets for both sweet and sour as well as firm and less firm apples, because different products will be needed for different consumer segments to satisfy individual preferences.

The present work lays a cornerstone for the sensory characterisation of domestic apple and invites a fresh and at the same time scientifically based discussion on the topic. Future studies should focus on the most promising cultivars and their storage life as well as on the preferences of different consumer segments. Although additional studies may be needed to examine the storage performance and pleasantness of further cultivars, the study contributes to the understanding of the basis of the preferences and attitudes of domestic apple consumers. While the thesis concentrates on apples, the results will hopefully benefit research on other fruits and berries as well as provide insights to the process of consumer food choices and repeated methods in general.

PREFACE

LIST OF ORIGINAL PUBLICATIONS

This thesis is based on the following original articles, which are referred to by their Roman numbers (I-IV).

I   Seppä L, Railio J, Mononen R, Tahvonen R, Tuorila H. 2012. From profiles to practice: Communicating the sensory characteristics of apples to the wider audience through simplified descriptive profiles. LWT- Food Sci Technol 47:46-55.

II   Seppä L, Peltoniemi A, Tahvonen R, Tuorila H. 2013a. Flavour and texture changes in apple cultivars during storage. LWT- Food Sci Technol 54:500-512.

III   Seppä L, Railio J, Vehkalahti K, Tahvonen R, Tuorila H. 2013b. Segmenting consumers based on their perception of an ideal apple and subsequent apple choices. J Sens Stud 28:346-357.

IV   Seppä L, Latvala T, Akaichi F, Gil JM, Tuorila H. 2014. What are domestic apples worth? Hedonic responses and information as drivers of willingness to pay. Manuscript under revision.

The author's contribution

The author Laila Seppä organised the data collection in all the stages of the experimental work. She was responsible for the analyses, the interpretation of the results and the conclusions. She was the main corresponding author of the publications I-IV. Contribution was received from the co-authors during all the stages of the work: designing the experiments, implementing data collection, and analysing the data. The co-authors commented on the manuscripts at various stages.

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In addition some unpublished material is presented.

ABBREVIATIONS AND SYMBOLS

1-MCP	1-methyl cyclopropane
ANOVA	Analysis of variance
°BRIX	Soluble solids
CA	Controlled atmosphere
CL	Cluster
CSI	Change Seeker Index
DD5	Degree day, cumulative base temperature over 5°C during growing season
F	Female gender
GDA	Generic descriptive analysis
HedFlex	Hedonic flexibility, the largest difference between the liking scores of the products chosen by a participant over the sessions
M	Male gender
MTT	Agrifood Research Finland
n	Number of panelists in a panel or substudy
p	Level on significance
PC	Principal component
PCA	Principal component analysis
r	Pearson correlation coefficient
R	Round
RGM	Repertory grid method
RH	Relative humidity
SD	Standard deviation
TR	Treatment
wo	Without
WTP	Willingness to pay
y	Years

1 INTRODUCTION

Food is eaten for nourishment, but choices are made mainly based on other factors, such as liking the product. The physical and chemical composition of food forms the basis of its appearance, smell, taste and texture, which are experienced through senses (Cardello 1996). The complex sensory interactions between the perceptions and the participation of other factors, such as saliva production, mastication and the food itself determine the actual perception (Barrett et al. 2010; Salles et al. 2011). Analytical sensory methods like generic descriptive analysis (GDA) can be used to measure and differentiate the sensory profiles of food. Because the food perceptions encompass also a hedonic dimension, analytical methods need to be combined with consumer methods to measure consumer quality accurately. In this way products can be positioned into the market based on their sensory attributes and consumer response so that the reasons for the acceptance or rejection in a specific consumer segment or in general are traceable.

Fruits typically differ greatly in the intensities of their sensory properties even within a cultivar, making the measurement of their characteristics challenging (Harker et al. 2002a; Harker et al. 2003). Consumers may not be aware of the quality factors nor of this inherent variability within the produce, which may lead to disappointments. The inclusion of vegetables and fruits in the daily diet is highly recommended by governmental and health organisations (Anon. 2005; Nord 2013; WHO 2003). Low fruit and vegetable intakes have been recognised as a major risk contributing to mortality due to non-communicable diseases such as cardiovascular diseases and cancer. Currently there are large differences in the consumption between the genders and geographical areas also in Finland (Findiet 2013). Increasing fruit and vegetable consumption would be enhanced with multilevel co-operation between nutritional, educational, marketing and sensory specialists.

Apples (*Malus domestica* Borkh) are the second most consumed fruit after oranges in Finland, with an annual consumption of about 9.3 kg/person, of which domestic apples account for 4-6% (FAO 2013; Finnish Customs 2013; TIKE 2013). During the past few years the cultivation of domestic apples and their availability in the market have increased. However, there has been a very limited knowledge of 1) the characteristics of the cultivars and the way these characteristics progress during storage and 2) the preferences, attitudes and perceptions of Finnish apple consumers related to apples and the reasons behind them. Therefore in 2009 a research project funded by the Ministry of Agriculture and Forestry was launched focusing on the sensory properties of domestic apples and consumer responses.

The present thesis is based on the studies performed during three harvest years (2009-2011) and published in four original articles. The thesis concentrates on the prospects of domestic apple production and consumption by developing sensory profiles for selected apple cultivars, and relating these to consumer responses on apples. In the thesis domestic apples are understood as apples grown and harvested in Finland although the cultivar strain itself may be of non-domestic origin. In addition to being eaten fresh, apples can be used for manufacturing snacks, cooking, baking and cider-making. This thesis concentrates on apples that are eaten fresh and unprocessed.

The descriptions of the apples established in this research will be utilised in the selection of the cultivars suitable for the new production. They will also be used to aid informing the retail sector and the consumers on the characteristics of the cultivars. The results of the consumer sub-studies are beneficial in gaining understanding of the preferences and attitudes of Finnish consumers towards domestic apples. The literature review discusses first the determinants of food quality and liking and explains the basis of sensory research. Then it focuses on the apples, first on their background and further on their sensory quality related issues including consumer perception of apples.

2 REVIEW OF THE LITERATURE

2.1 Sensory quality of food

Food is one of the basic elements of our daily life. It consists mainly of proteins, carbohydrates, minerals and fat which are used by the body to produce energy and to enhance growth, repair and vital processes including breathing and thinking. However, food is much more than the sum of its energy and nutrients. The attitudes, preferences, memories and expectations of the person consuming food have a significant impact on how and in which way the food is experienced. In addition, especially with natural products, the composition and shape of the food varies.

In the ISO 5492 standard (2010), the term "quality" refers to the collection of features and characteristics of a product that confers its ability to satisfy stated or implied needs, while "attribute" is defined as a perceptible characteristic. From the consumer perspective quality is often defined in terms of acceptance, "consumer quality", such as very good, good, fair or bad. It implies to the excellence of a product (or lack of it), referring to the certain properties or attributes of the product (Barrett et al. 2010). Quality can be used in reference to percept that makes it unlike other sensations (Breslin 2013), for example taste qualities like sweetness. There are also concepts sensory, microbiological and nutritional quality. Cardello (1995) pointed out using nutritional quality as an example that it is not the actual nutrient content that is important, but the *perception* of that quality. He defined food quality as having the following properties: 1) consumer is the referent, 2) acceptability is the key measure of it, and 3) judgments are relative to the product category and target market.

Food quality can be regarded as an equivalent to acceptance and is therefore influenced by situational factors such as appropriateness (Cardello 1995; Kramer et al. 1992). Cardello (1996) divided food quality based on food acceptance into four measurement levels: Physical, sensory, perceptual and hedonic levels. The physical level consists of the physical and chemical structures of the food, onto which other levels are based. The sensory level contains basic sensations, while the hedonic level explains how much (and how) the food is liked. The perceptual level consist of flavour, texture and appearance profiles such as how the food looks, smells and tastes, and is further transferred into hedonic experience. "Perception" can be understood as a conscious awareness of the input from the senses that result in experience (Breslin 2013).

2.1.1 Perception of food

The physical and chemical composition of food forms the basis of its perceived properties – appearance, smell, taste and texture – which are experienced through senses, the 'sensory level' as defined by Cardello (1996). The main senses involved are vision, olfaction, taste (gustation), touch and hearing, sketched in **Figure 1**. The sensory properties of food change during mastication as a result of chemical and biochemical reactions aided by the saliva, enzymatic reactions and chemical composition of the food (Barrett et al. 2010; Salles et al. 2011). Complex sensory interactions between the perceptions and the participation of other factors such as saliva production ultimately determine how the food is perceived, which Cardello (1996) calls the 'perceptual level'. Sensory organs adapt to the stimuli during prolonged exposure (Cardello 1995; Cardello 1996; Salles et al. 2011). In addition, individual scaling and synergistic and antagonistic interactions affect the intensity of flavour perception (Salles et al. 2011).
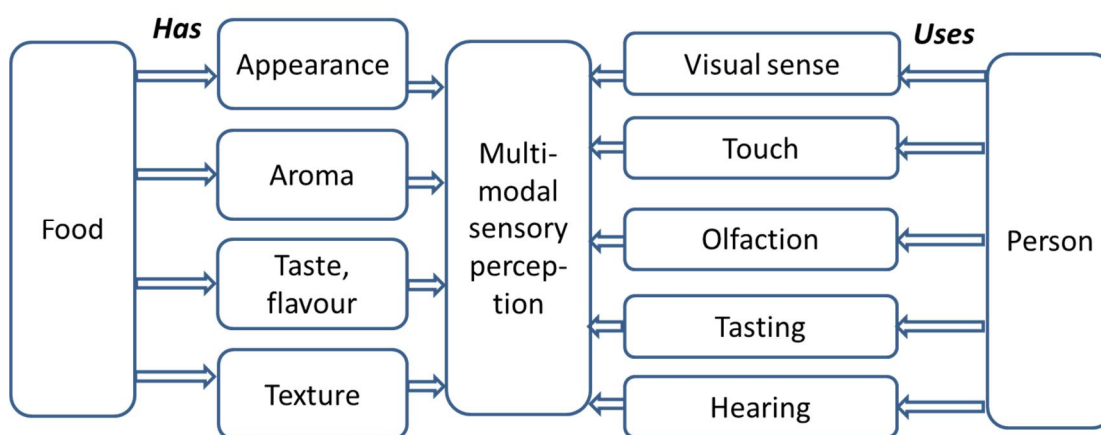
Figure 1. The main senses and food attributes involved in the multimodal sensory perception of food.

The properties of food are called attributes when they are measured with sensory methods. Most of the attributes are experienced with multiple senses by multimodal interactions (**Figure 1**). For example, texture can be examined by hand (touching or breaking), eyes, ears and mouth. Perception of texture in the mouth depends on the interaction of the food matrix with teeth, saliva and oral mucosa (Salles et al. 2011). The food is transformed into bolus through thermo-mechanical shearing and compression actions by the teeth, cheeks and tongue. The oral cavity encompasses mechanoreceptors which respond to the tactile sensations created by the food particles during mastication. The texture and flavour of the food are perceived during all the three phases of oral food processing: ingestion, mastication and swallowing.

Flavour is a complex synthesis of olfaction, taste and chemosensory perception, and texture adds nuances to the perception. Flavour perception is due to the amount and composition of

volatile and non-volatile compounds in the food (Barrett et al. 2010: Salles et al. 2011). The availability of these compounds depends on the time elapsed and breakdown of the food matrix during chewing. The flavour compounds are released from the food to the saliva phase during mastication (Salles et al. 2011). Non-volatiles are sensed by the taste buds of the tongue, while volatiles are transported via throat to the epithelial tissue in the nose housing olfactory receptors. It is believed that the sense of taste is used to screen both the nutritious and hazardous compounds from the food during chewing (Breslin 2013).

There has been a lot of effort to develop instrumental sensors to monitor sensory properties. Through human senses and physiology it is possible to gain information that would not be available with mere instrumental or chemical methods. Most chemical and other non-sensory methods measure the composition of the food *per se*, not how and in which order these components are perceived (Hampson et al. 2000; Harker et al. 2006; Ross 2009; Salles et al. 2011). Some of these methods have only moderate correlation with a sensory measure, while in some cases they provide useful information. Their main value is in screening out the most unwanted products (e.g. Harker et al. 2008; Herregods 1999). As most of the food perceptions contain also a hedonic, pleasure dimension in addition to the basic dimensions of the food itself and its quality, consumer quality can only be measured accurately using sensory and consumer methods (Barrett et al. 2010; Ross 2009).

2.1.2 Hedonic responses as predictors of consumption

Consumer acceptance research examines reasons influencing liking of a food product (Cardello & Schutz 2006). It involves both the intrinsic and extrinsic product factors as well as cognitive, demographic, social and attitude factors of the person ingesting the food. Attitudes aid in organizing information from the environment, although they are not directly visible (Triandis 1991). Moods are similar to attitudes, but they refer to the more general tendency to respond in a certain way. The development and maintenance of food acceptance is controlled by many affective, personal, cultural and situational factors (Martins & Pliner 2005). In addition to the sensory properties of the product, variables such as the price and product information along with the moods and emotions can affect hedonic (affective) responses (Jaeger 2006). These reactions are highly context-specific and are affected by expectations (Cardello 1995; Cardello 1996). Typical consumer variables studied include liking, choice, purchase intention and consumption of food or other commodity.

According to Mela (2001), "liking" refers to an immediate qualitative, hedonic response to a food and the degree of experienced pleasure or displeasure, while "preference" expresses choice among alternatives. Preference is sometimes used as a synonym to liking or to indicate purchase decision, which may lead to misunderstanding. Liking contributes to the preferences and purchase intentions, but it is only one of the many factors leading to these

decisions (Cardello 1995; Mela 2001). Liking and preferences are partly affected by genetic predisposition (e.g. Hayes et al. 2013; Keskitalo 2008; Törnwall 2013).

Past experiences together with the reward from the present situation form a cycle of further learning and experience. Typical rewards are satiety, psychophysical effects and reinforcement, which contribute to the formation of likes (Mela 2001; Mela 2006). The social dimension of eating is of great importance. Food served at the wrong time or in the wrong situation is considered inappropriate (Kramer et al. 1992; Schutz 1988). Consequently, environmental cues, including the food itself, have an important role in the willingness to eat. When individuals were asked to explain their choices, sensory and pleasure factors (especially taste) and healthiness were most often mentioned (Martins & Pliner 2005; Roininen & Tuorila 1999). Moreover, the desire to eat a particular food is formed from the balance of 1) the physiological state, such as hunger, 2) the expected pleasure of eating that food (often the result of learning), and 3) the external stimuli and cues (Mela 2006). **Figure 2** presents a sketch of selected situational and background variables involved in the perception of food.
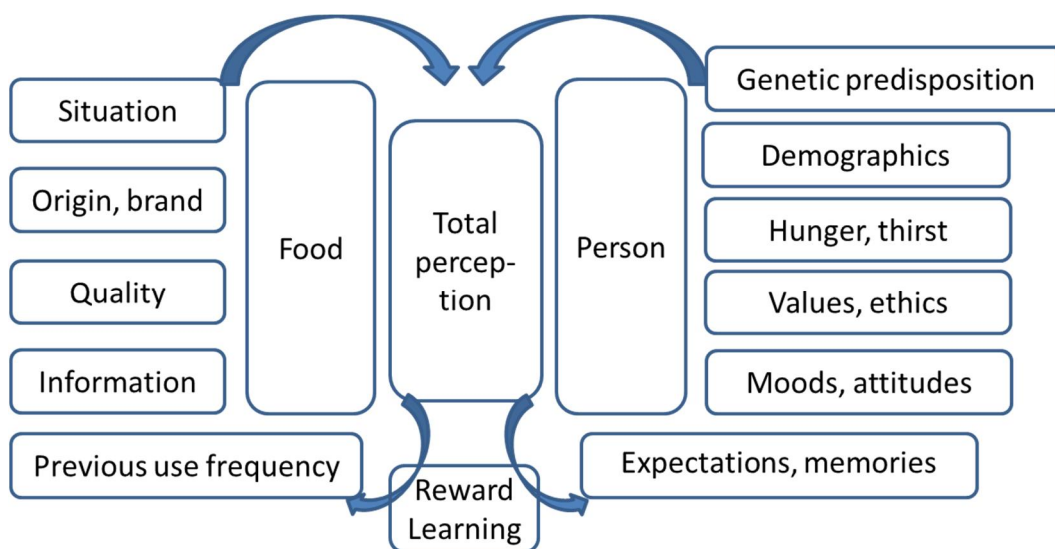
Figure 2. Schematic representation of selected situational and background variables involved in the total perception of food.

Hedonic responses can be measured either directly in relation to the physical food sample, or indirectly, such as enquiring about food names and measuring the liking these names cause. External cues such as information can have great effect on the hedonic responses to the product, regardless of its actual sensory quality (Cardello & Schutz 2006; Kähkönen et al. 1996). The effect on the hedonic ratings may be due to the expectations following exposure to information. Information may include brands, labels, ingredient details and health claims as well as general nutritional information. Good brands may be the most valuable asset a company has (Jaeger 2006). Influence of information is sensitive to the wording, timing and

context of information (Cardello & Schutz 2006; Kähkönen et al. 1996; Pohjanheimo & Sandell 2009).

2.1.3 Healthy eating and the role of fruit

While research has demonstrated the effects of the quality and quantity of food on the general health status, unhealthy and excess eating has become more endemic, resulting in for example obesity and cardiovascular diseases. Although reasons behind non-communicable diseases are complex, it seems that some explanation may lie in the differences in the perception of sensory stimuli, liking and wanting (Mela 2006). Healthy food is healthy only if it is consumed. For example food neophobia, individual preferences, moods and emotions can affect the choices and preferences considerably (Kähkönen & Tuorila 1999; Martins & Pliner 2005; Mustonen et al. 2007; Pohjanheimo et al. 2010; Roininen 2001).

Fruits, berries and vegetables provide a rich source of fibres and nutrients and their inclusion into the daily diet is encouraged by governmental and health organisations (Anon. 2005; Norden 2012; WHO 2003). Finns eat annually about 45 kg fresh fruits and 32 kg vegetables and salads, but the quantities vary considerably between geographical areas and consumer groups (Findiet 2013). Thus, further nutritional information and guidance is needed so that the information on the benefits of healthy eating spreads further. For example, Hartmann & Maschkowski (2009) call for use of new and different marketing strategies, like short stories, to promote fruits and vegetables especially among the children. Fruit and vegetable intake correlates strongly with liking among children (e.g. Caporale et al. 2009). Consequently, it is of high relevance to offer fruit and vegetables with high sensory quality (Bonany et al. 2013; Harker et al. 2008; Sijtsema et al. 2012). Sensory science, by spreading knowledge of appropriate attributes relevant to fruit quality, would be a useful tool to promote consumption, at all levels of the food chain, literarily from the field to the fork and beyond.

Internal quality, such as agreeable texture and flavour of the fruits is important to the consumers, but it is difficult to predict accurately by visual inspection. When aiming to improve the quality of the fruits, different variants are needed for different consumer segments (Harker et al. 2002a; Harker et al. 2003; Jaeger et al. 1998). In a study by Campbell et al. (2009), the quality of the fruits in the supermarkets varied considerably during the four-week experiment, although they were within the quality criteria of the fruit industries. Consumers face fruit-to-fruit variability in their everyday life, but they might not fully understand reasons behind this variability and what a "natural product" actually means. The shoppers are not always aware of the long storage times of apples aided by modern technology, but may assume that during off-season, the produce comes from the other hemisphere (Lund et al. 2006).

Jaeger (2006) pointed out that convenience is an important concept in today's world. For example for fruits, convenience requires that they 1) are available in most shops and around the year, 2) have good storability and do not bruise easily, 3) they are not messy to eat, and 4) can be used for many purposes. Apples and bananas are mentioned as good examples of convenient products. Apples are generally very popular among the fruits and snacks. Consumers considered them convenient, healthy, natural and easier to digest compared to dried fruits (Sijtsema et al. 2012). Apples were rated as one of the most popular snacks by adolescents taking part in the study on real choices of snacks (Mielby et al. 2012). The majority of Danish 9-13 years old children studied reported eating apples at least a couple of times a week (Kühn & Thybo 2001a). Roininen & Tuorila (1999) observed that 33% of the participants in a sensory study chose an apple as a reward for completing the task instead of a chocolate bar. The main reasons for choosing the apple were health and nutrition related, followed by good taste and momentary desire.

2.2 Methodology relevant for the present study

To study the sensory properties of a product, two main categories of methods are used: analytical methods and consumer (affective) methods. The analytical studies are mostly done using a trained panel, while the affective methods have ordinary consumers as respondents, who represent either all the consumers or a segment of them, such as young women, students, elderly population or those who use frequently the product in question. The aim is to gain subjective information of the product using hedonic ratings. With a trained panel, it is possible to gain objective knowledge of the product. The panel is trained to pay attention to certain attributes and to measure their intensities. Without the information gained through the analytical methods, it would not be possible to know exactly what features of the products are those that attract consumers. On the other hand, without consumer studies there is no knowledge whether the sensory characteristics of the product have any effect on the liking of that product (Cardello & Schutz 2006; Péneau et al. 2007).

2.2.1 Descriptive methods

Descriptive methods such as generic descriptive analysis (GDA) are the most common analytical methods. Descriptive methods can be used to characterise and differentiate the investigated products (Lawless & Heymann 2010). According to the ISO 5492 standard (2010), descriptive analysis is any "method to describe or quantify the sensory characteristics of stimuli by a panel of assessors".

GDA is used to determine the intensities of the various attributes usually set during the panel training. The order and the way in which the attributes are evaluated are also decided during the training. The optimal size of a trained panel is 8 to 15 members (Cardello et al. 2011; Lawless & Haymann 2010). Performing GDA is challenging, as the sensory attributes are often linked with each other, either directly or through background variables. The trained panel is expected to perform the evaluations objectively, without hedonic responses. However, the dimensions that are measured through sensory descriptors in GDA should have relevance to the consumers of that product (Lawless & Heymann 2010; Péneau et al. 2007). Thus, co-operation with consumer research is essential to gain meaningful results through GDA.

2.2.2 Consumer responses to food

The members of a consumer panel are untrained, but some may have previous experience of serving in consumer-type panels (Cardello et al. 2011). The ratings given by consumers are subjective as the aim is to find out the perceptions and opinions of naive people. Consumer panellists should be available and willing to participate in the panel work and preferably represent the current or future target group of the product. As the ratings are subjective and prone to high variability, panel size should be adequate, between 40-100 members.

The most common scale used is a 9-point verbally anchored hedonic scale, 'Like extremely' – 'Dislike extremely' (Cardello & Schutz 2006, Peryam & Pilgrim 1957, Tuorila et al. 2008). It is possible to ask about pleasantness or alternate the anchors or the number of points. As often when doing sensory research, translations between languages may be challenging (Andani et al. 2001; Galmarini et al. 2013). For example in Finnish there is no direct term for "dislike". Cardello et al. (2011) recommend that consumer panellists are not asked to differentiate their perceptions, but rather to express their liking or disliking. However, asking them to report their comments on the products can be helpful at later stages of the study, when results are analysed. Open-ended questions can also be useful (Cardello & Schutz 2006, Roininen 2001).

In a typical shopping situation, consumers are able to examine only the extrinsic properties of the food product, such as colour and size. Repeated purchases and demand for the product ultimately depend on whether consumers like the sensory properties of the food they have bought (Harker et al. 2008; McCluskey et al. 2007; Mustonen et al. 2007). Ideal sensory profiles of products have interested researchers since 1970's (Moskowitz et al. 1977; Szczesniak 1979), and still are of interest (Ares et al. 2011; Jaeger et al. 2003), although such ideal products have limitations as consumers differ from each other in their perception, preferences and attitudes. Without considering individual differences we offer only products that are acceptable to most of the consumers, but rarely delight any of them, such as meals

during flights (Lawless & Heymann 2010). Thus, segmenting based on hedonic ratings or other consumer-related variables is a vital part of sensory consumer research.

Demographic background including gender and age may have a role in liking and choices. Pohjanheimo & Sandell (2009) showed that domestic origin of berry yoghurts was more important to the older than to the younger generation. The elderly may find fruits and vegetables troublesome to eat, but differences between cultures and countries can be substantial (Roininen et al. 2004). Being male usually reduces the consumption of fruits and vegetables (Findiet 2013). In addition to demographic data, respondents participating in a consumer study are usually asked to report their use frequency of the product in question.

Various attitude and behavioural scales are available to gain a wider perspective on the background and attitudes of the respondents, such as health attitude and involvement scales and Change Seeker Index (Steenkamp & Baumgartner 1995). A selection of these scales has been published in Finnish (Roininen 2001; Urala et al. 2005). The information collected can be used to segment the respondents and to explain and discuss their preferences. For example attitudes towards healthy eating have been used as a clustering criterion (Carrillo et al. 2011; Pohjanheimo et al. 2010).

The price paid for food, consumers' willingness to pay (WTP), is of major interest in the fields of sensory and consumer sciences. WTP can be studied with hypothetical and non-hypothetical methods. The major difference between the two categories is that the non-hypothetical methods use real products and real money in the research, while the hypothetical methods are, literally, hypothetical. Consequently, the main limitation of the hypothetical methods is that the respondents are not responsible for their decisions as they would be in a real market situation, because they do not have to reveal their true WTP. There may be a substantial inconsistency among individuals between their answers to hypothetical questions and what they would actually do (Jaeger 2006).

WTP and related studies have been implemented as mail (Wang et al. 2010) or internet surveys (Denver & Jensen 2014; Jaeger & MacFie 2001) as well as using interviews or face-to-face questionnaires (Kallas et al. 2011), often without any real samples. However, to conduct a non-hypothetical study, real products need to be present. Choice experiments (Denver & Jensen 2014; Kallas et al. 2011; Yue & Tong 2011) can be either hypothetical or non-hypothetical, while experimental auctions (Costanigro et al. 2014; Grebitus et al. 2013; Lange et al. 2002; Lund et al. 2006) are non-hypothetical. In addition to asking WTP *per se*, WTP has been measured relative to some other sample or product. Costanigro et al. (2014) studied WTP for upgrading conventional apples to local, organic or local-organic produce, while Lund et al. (2006) measured the effect of trading fresh and stored apples.

Experimental auction methods have been used to study consumers' actual willingness to use money for a wide range of products, such as Champagne (Lange et al. 2002), wine (Combris

et al. 2009; Grebitus et al. 2013), spelt (Stefani et al. 2006), genetically modified foods (Jaeger et al. 2004), and orange drink (Noussair et al. 2004). Apples have been the target of interest in numerous settings (e.g. Costanigro et al. 2014; Lund et al. 2006). The most common methods of experimental auction are Vickrey auction of 2nd (Grebitus et al. 2013; Lange et al. 2002) or nth (Stefani et al. 2006) price method and Becker-Degroot-Marschack (BDM) auction (Becker et al. 1964).

2.3 The apple

Apple (*Malus domestica* Borkh) belongs to the family *Rosaceae* alongside with pear, plum and cherry. It was cultivated already 4000-5000 years ago in China, Assyria and Egypt (Krannila & Paalo 2008; Simonen 1961; Tahvonen 2007). The town along the Silk Road, Almaty (formerly Alma Ata), translates to "Father of Apples" or "Full of apples". Although the forbidden fruit in Genesis was probably fig or pomegranate, in religious art it is often depicted as an apple, and apples are mentioned in Bible several times. For example, King Solomon asked: "…comfort me with apples…". Apple is familiar to us also through many figures in legends and fairy tales like Wilhelm Tell and Snow White.

The Romans introduced cultivated apples, and techniques like grafting, to Britain and other areas they conquered, although even before their time, local varieties existed (Simonen 1961; Twiss 1999). Through the Dark Ages apple cultivars were kept safe in the monasteries. Later, kings, noblemen and clergy have promoted fruit orchards by hiring fruiterers and gardeners in Central Europe, Britain, and also in Finland, where apples have been cultivated for hundreds of years (Krannila & Paalo 2008; Simonen 1961). Apple cultivation was introduced to Finland through two routes: to Turku and South-West coast from Sweden (under which rule the main part of Finland was at that time) and to Vyborg and Karelia from Russia and Baltic. One of the earliest mentions of apples is from the 15th century in Vyborg. As Finland is a Northern country, domestic apple horticulture has suffered repeatedly from hard winters and occasionally apple gardens have perished to the edge of extinct.

2.3.1 Apple markets

Apple is one of the most widely cultivated fruit in the temperate zone of the world. The annual commercial production is between 70 000 (WAPA 2013) and 75 000 million kg (FAO 2013). The top five producers in 2011 were China, USA, India, Turkey and Poland, which constitute over half of the annual world crop. The major exporters were China, Italy, USA, Chile, France and Poland (FAO 2013). 'Golden Delicious', 'Gala', 'Idared' and 'Red Delicious' are the major cultivars cultivated in Europe, while in the USA they are 'Red

Delicious', 'Gala', 'Golden Delicious' and 'Fuji' (WAPA 2013). Genetic variation within these major cultivars is minimal due to the breeding programs' favouring of certain genotypes. 'Gala' originates from New Zealand, 'Fuji' from Japan and the others from the USA.

Commercial domestic apple production has doubled since 1995, when Finland joined EU, and was 4.8 million kg in 2011, accounting for 4-6% of the annual consumption (Finnish Customs 2013, Tike 2009; Tike 2013). The major importers are Italy, France, Poland and The Netherlands. During late spring apples from South-American countries Argentina, Brazil and Chile are imported substantially. Domestically grown apples are seasonal products with relatively short storage life, available from around August to the Christmas time (Dris 1998; Tahvonen 2007). Only recently some new cultivars have shown promise to extend the apple season further.

Due to the clear differences in weather conditions between the seasons, Finns are well aware of the seasonal nature of the crops, although imported apples are available throughout the year. Even in Poland and Germany, apples are regarded as all-around-the-year-products, while peaches are considered seasonal fruit (Konopacka et al. 2010). In the major apple producing countries, controlled atmosphere (CA) cold storage rooms are widely used to optimise ripening of apples and to extend their commercial life for the whole year (or even beyond). Due to the small scale production, CA storage facilities are not commonly available in Finland. In addition, application of 1-MCP (1-methyl cyclopropane), another method to slow down ripening and enhance storage life, is not allowed.

In Finland, domestic apples are valued for their flavour and cleanliness (i.e. minimal remnants of pesticides and other farming chemicals) (Mäkinen & Malkki 2004; Malkki 2007). There are abundant local varieties with unique aroma and flavour, which have adjusted to the harsh climate, such as extremely cold winters (over -30°C) and spring frost (up to -10°C) during blooming (Krannila & Paalo 2008; Meurman & Collan 1943; Tahvonen 2007). Unfortunately, many of these varieties have short storage life and modest sensory quality. As most orchards are small family-owned farms, apple cultivation has been quite small-scale and too unorganised to meet the demands of a modern fruit and vegetable market (Mäkinen 2003; Malkki 2007). Very recently some new facilities have been built in Southern Finland, where small producers can store their crops in standard cold storage conditions.

During the past few years cultivation of apples and their availability in the market has increased, aided among others by the long-term studies by MTT, aiming at breeding new cultivars and developing cultivation techniques suitable for the climate (Kaukoranta et al. 2010; Tahvonen 2007). At the moment apple cultivation is commercially feasible in Southern and South-Western part of the country, but global warming is expected to expand the area northwards (Kaukoranta et al. 2010) and the importance of domestic apples in the economy will rise.

In spite of the brighter future, some perils loom. In Finland, effective cultivar branding has not yet begun, and there are also some attitude issues in the retail sector and even among the consumers. In some areas of the country the availability of the domestic apples is poor, while in others there is oversupply. The fruit market is challenging, as standard-quality imported apples are often sold at a very low price (1–2 euros/kg), while local apples might cost as much as 4–5 euros/kg. In addition, home gardens bear a multiple amount of yield compared to the commercial production, which does not show in official statistics, but may reduce the appreciation of domestic commercial produce as the quality of these home-grown fruits is usually quite poor. In addition, imported apples are often used as special offers to draw customers to the stores.

Domestic apples are normally sold with only the name of the cultivar with no other information (and sometimes not even the name is shown), unlike for example potatoes, of which information of their typical characteristics is available for the shoppers. Well branded and presented domestic apples of premium quality would create added value in the fruit and vegetable sector. Consequently, to promote the demand for domestic produce, marketing efforts should aim at emphasising the positive quality characteristics of domestic apples and the reasons behind their higher price. Furthermore, wider knowledge of consumers' attitudes towards these apples would aid branding. For example, questions like 'are there other issues than colour and flavour that consumers value in domestic produce and which are worth stressing in the marketing campaigns' are very relevant to discuss.

2.3.2 Domestic cultivars

Domestic cultivars are classified as summer, autumn and winter, or early, mid and late season cultivars, respectively, but the division between categories is not strict. Categories are based on the DD5 requirements of the cultivars (Kaukoranta et al. 2010; Tahvonen 2007). DD5 is "degree-day", the cumulative base temperature over 5°C during growing season, and describes how much warmth is needed for yield. In South-Western Finland, DD5 is 1300–1400 (Finnish Meteorological Institute 2013), although the area is geographically at the level of South Greenland and Anchorage, Alaska. As the trees need to prepare themselves for the winter and the blooming of the next summer (i.e. reach vegetative maturity and hardening), the whole amount of DD5 available cannot be used for fruit ripening (Tahvonen 2007). Summer cultivars are picked at commercial ripeness, while autumn and winter cultivars have to be harvested before they are ripe because of the oncoming winter. They are ripened in cold storage until they reach commercial maturity. This takes typically 2-4 weeks, after which they can be stored up to several months.

Many traditional cultivars, such as 'Antonovka' and 'Transparente Blanche' ('Valkea Kuulas' in Finnish), originate from Baltic or Russia, or from a single local seedling, like 'Huvitus', which serves as a rich source of breeding material in the breeding program of MTT. 'Lobo' originates from Canada and comprises currently one third of the commercial production (**Figure 3**). Alongside with 'Huvitus', 'Lobo' is much used in breeding (Tahvonen 2007). Very seldom do natural seedlings bear fruits of good eating quality. Apple trees are mainly obtained through grafting. In grafting, branches are inserted in to rootstocks to give new trees of the same cultivar as the branch was. In Finland, small sized rootstocks are mainly used nowadays, resulting in smaller trees than before. Thus, new orchards have more trees in a hectare than old orchards and, consequently, higher crops per hectare.
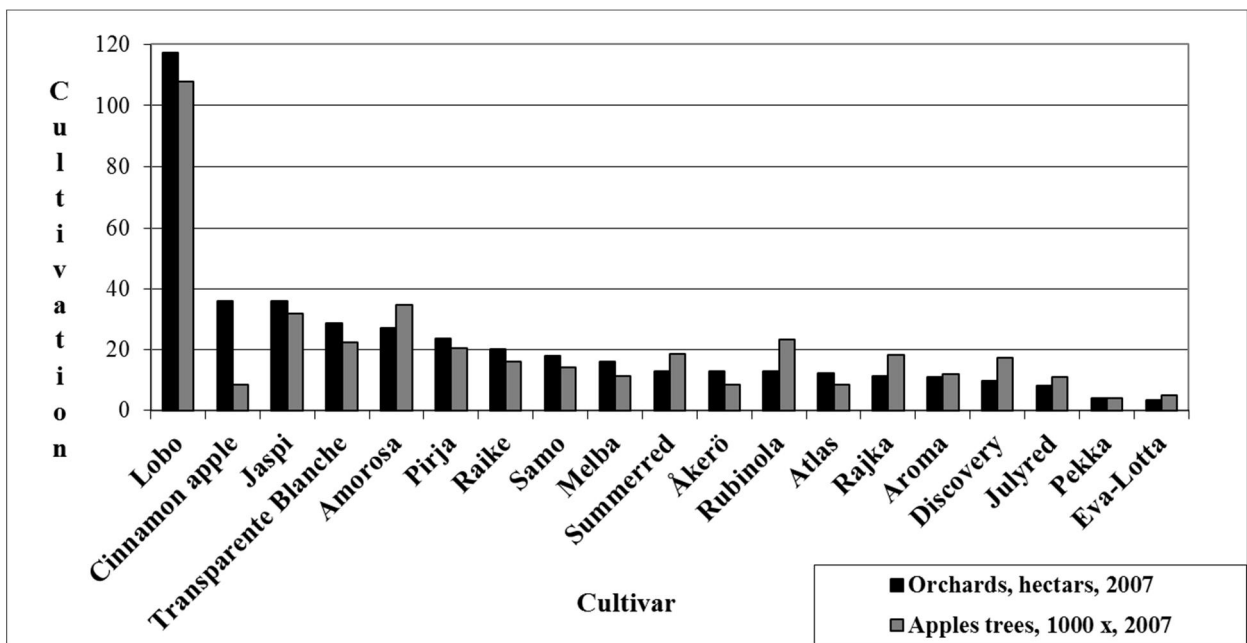
Figure 3. The most widely cultivated domestic cultivars in commercial orchards (Tike 2009).

Production of 'Aroma' is increasing rapidly, and in 2007, 'Aroma' (along its red variant 'Amorosa') was the second most common cultivar. Commercial cultivation of the traditional cultivars 'Cinnamon apple' and 'Transparente Blanche' is decreasing rapidly, but they are still very popular in home gardens. The world's leading cultivars cannot be cultivated in Finland because they lack tolerance towards cold weather (Tahvonen 2007). New cultivars are introduced to production through two routes: they originate from those areas where the climate is at least remotely similar to Finland, such as other Nordic countries or Canada ('Aroma', 'Summerred', 'Eva-Lotta' and 'Discovery'), or they are new crosses produced domestically ('Jaspi', 'Pirja' and 'Pekka').

2.3.3 Apple fruit

Apple is a climacteric fruit, which means that it continues ripening after it has been harvested, whereas non-climacteric fruits do not ripen anymore after harvest (Kader & Barrett 2005). Examples of the latter are pineapple, berries like strawberry and raspberry, and citrus fruits.

The time from the pollination to a ripe apple is about five months (Janssen et al. 2008; Tukey & Oran Young 1942), but varies from around 100 to almost 200 days (Anon. 2012). During the first month after the pollination the cells divide, after which they start to expand and starch begins accumulating (Janssen et al. 2008). Finally, during the last six weeks, the starch breaks down to sugars. The fruit flesh, surrounded by the epidermis (skin), develops over the carpel and petal bundle of the flower, which are still visible in the mature fruit (**Figure 4**).
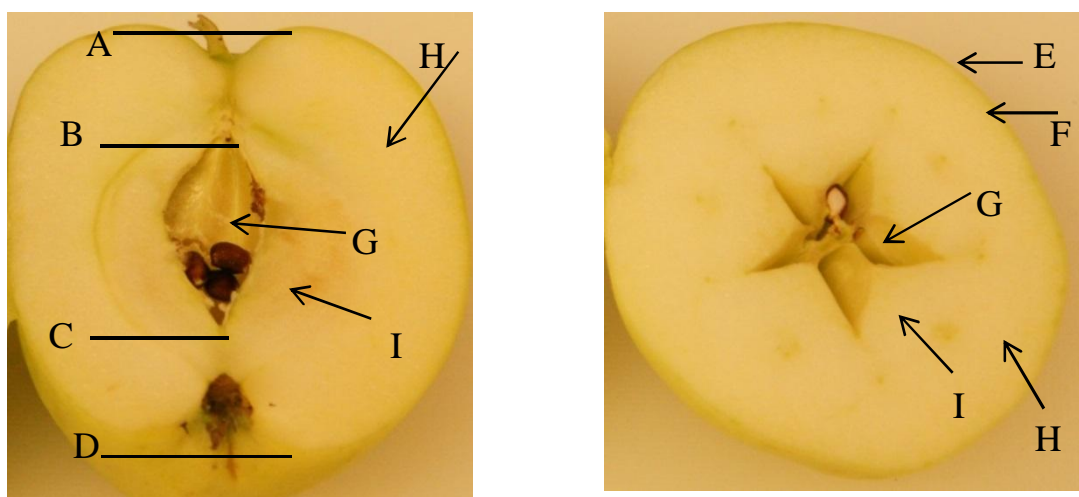
Figure 4. Vertical and horizontal cross sections of an apple. Terms according to Tukey & Oran Young (1942). A-D length of fruit, B-C length of carpel, E epidermis, F hypodermal layer, G petal bundle, H cortex, I pith.

Tukey & Oran Young (1942) showed that early season cultivars increase in size (both diameter and volume) more rapidly and in a shorter time than late season cultivars, and concluded that growth pattern is a cultivar specific characteristic. The growth curve becomes more flat during the state of advanced maturity (Bizjak et al. 2013). The apple blooming in Finland takes place at the end of May and lasts for 4-6 days. The weather conditions during the blooming have a great impact on the resulting amount and quality of fruit (Tahvonen 2007). For example, a heavy hailstorm or a severe spring frost can destroy the whole year's yield.

In addition to water, mature apples contain sugars, acids (mostly malic acid) and minor components such as minerals, flavonoids and vitamins, but a minimal amount of starch

(**Table 1**). A little over half of the sugars are fructose, followed by sucrose, glucose and sorbitol (Bizjak et al. 2013; CoFIDS 2002; Fineli 2013; USDA 2013). The relative amounts of the sugars change during advanced ripening, but depend also on the cultivar and harvest year (Bizjak et al. 2013). Apples comprise of a substantial amount of phenolic compounds and antioxidant activity. The total amount of phenolic and other bioactive compounds can vary manifold between cultivars and harvest years (Łata & Tomala 2007; Wolfe et al. 2003). The peel contains a significant amount of these compounds, even more than the flesh itself, and is thus an important source of these health-promoting substances.

Table 1. Mean composition values for 100 g edible portion of raw, mature apples.

Apple type	Energy	Water	Carbo-hydrates	Organic acids	Sugars	Fibers	Vitamin C	Source
	kJ	g	g	g	g	g	mg	
Domestic, average with skin [a]	149	na	7.1	0.5	7.1	2.0	12.0	Fineli (2013)
Domestic, wo skin	170	na	8.3	0.5	8.2	1.8	8.0	Fineli (2013)
Imported, average with skin [a]	161	na	8.2	0.4	8.1	1.5	6.0	Fineli (2013)
Imported, wo skin	187	na	9.4	0.4	9.3	1.8	4.0	Fineli (2013)
Apples, with skin	232	85.1	12.4	na	10.8 [b]	1.8	12.0	NFA (2013)
Apples, without skin	263	85.1	14.6	na	10.5 [b]	0.9	8.0	NFA (2013)
Apples, with skin	225	85.3	11.3	0.5	11.3	2.0	6.5	Anses (2012)
Eating, average with skin	199	84.5	11.8	na	11.8	1.8 [c]	6.0	CoFIDS (2002)
Cooking, wo skin	151	87.7	8.9	na	8.9	1.6 [c]	14.0	CoFIDS (2002)
Apples, with skin	218	85.6	13.8	na	10.4	2.4 [d]	4.6	USDA (2013)
Apples, wo skin	201	86.7	12.8	na	10.1	1.3 [d]	4.0	USDA (2013)

na) data not available
a) edible portion 87%
b) monosaccharides and disaccharides
c) non-starch polysaccharides
d) total dietary

2.3.4. Ripening of apples

During ripening apples produce large amounts of plant hormone ethylene and warmth (Defilippi et al. 2004; Kader & Barrett 2005; Tahvonen 2007), while respiration rate is fairly low under optimum conditions (Kader & Barrett 2005). Acids and the starch granules are converted to sugars and used for respiration, and consequently overall sourness diminishes as fruits ripen. After harvest the apples are not connected to the mother tree anymore and should be cooled rapidly to slow down the ripening process and to prevent quality deterioration and weight loss due to cellular respiration processes.

The maturity stage at harvest has a notable impact on the composition, storability and sensory quality of apples (Kader & Barrett 2005; Kader 2008). For example, the synthesis rates of aroma and flavour components increase with ripening, but apples need to have reached a certain maturity stage to be able to continue ripening in storage (Kader 2008; Moya-Leon et al. 2007). Unripe apples are hard and sour and lack the typical colour and flavour of the cultivar. Kader & Barrett (2005) specified that apples are often picked *mature* but *unripe* so that they keep better and withstand handling. Yet, in the literature, the distinction between mature and ripe is not always clear and they are often used as synonyms.

According to Apples Grades Standard by USDA (2002), "Mature means that apples have reached the stage of development which will insure the proper completion of the ripening process. Before a mature apple becomes overripe it will show varying degrees of firmness, depending upon the stage of ripening process". Ripening is seen as a dynamic process, the ultimate result of which is over-ripeness, and it has strong correlation with textural changes. However, there is no exact turning point to specify when a fruit turns mature, ripe or overripe. The standard defines firmness stages as follows (USDA 2002):

- Hard: flesh is tenacious and flavour starchy
- Firm: flesh is tenacious but is becoming crisp, slightly starchy flavour
- Firm ripe: crisp flesh
- Ripe: flesh is mealy, and soft for the cultivar type
- Overripe: apple has progressed beyond the stage of ripe and is not suitable for commercial use; flesh is very mealy and soft

Flesh firmness and skin colour along with starch and soluble solids contents are typical indicators of maturity and ideal harvest time (Brookfield et al. 1997; Kader & Barrett 2005; Tahvonen 2007). Soluble solids are expressed as °Brix value, the amount of dry matter dissolvable to water, usually regarded as an equivalent to sugar content of the fruit. Calculation of cumulative DD5 and quality observation, such as taste of the flesh or colour of the seeds and the skin, are other important methods for determining the harvest date.

Mature domestic apples have typically °Brix-values between 9 and 12 (Dris 1998; Nissinen & Kokko 2008; Tahvonen 2007). Herregods (1999), referring to several local studies, stated that ideal °Brix-value in France is over 13. Only few domestic cultivars reach this value (Dris 1998; Tahvonen 2007). Konopacka & Płocharski (2004) reported soluble solids values as high as 14 or more for some cultivars, while in a study by Iglesias et al. (2008), values for eight cultivars were between 12 and 13 during harvest and rose only slightly after that. During the last two to six weeks before harvest they rose by more than two units. Hoehn et al. (2003) showed that as soluble solids rose, 'Golden Delicious' and 'Elstar' apples became more liked. For 'Gala', no such difference was observed.

The maturing process in the orchard and consequently, sensory quality, is affected by the weather conditions, local microclimate, water available (e.g. irrigation), soil, age and the nutritional status of the trees, and cultivation practices as well as post-harvest factors (Dris 1998; Hampson et al. 2000; Kader & Barrett 2005; Kaukoranta et al. 2010; Tahvonen 2007). Even the site where an apple grows on the tree contributes to its quality. Cultivation practises have varying effects on different cultivars, and some practises may even reduce eating quality (Iglesias et al. 2008; Kader 2008; Tahvonen 2007; Thybo et al. 2005).

2.4 Sensory characteristics of apples

Quality attributes of a fresh, mature fruit include appearance, texture and flavour (Kader & Barrett 2005). Firmness, crispiness and juiciness are typical textural attributes, and flavour includes properties such as sweetness, sourness and astringency as well as off-flavours. Although instrumental methods have limited correlation with perceived sensory properties, some are widely used in rapid quality estimations as they are easy and quick to use (Harker et al. 2006; Tahvonen 2007). Commercial standards concerning firmness, ripeness or soluble solids have been developed by fruit producing countries and marketers (Harker et al. 2008; Herregods 1999). In addition, external properties are used as quality indicators (European Commission 2004; Richardson-Harman et al. 1998; Tahvonen 2007; USDA 2002).

Old cultivars with varying quality issues are common in all areas where apple cultivation has long heritage (Anon. 2012; Feliciano et al. 2010; Mehinagic et al. 2003; Mitre et al. 2009; Nissinen & Kokko 2008; Tahvonen 2007). Kader (2008) recommended replacing poor-flavoured cultivars in the orchards with new crosses having enhanced flavour properties. Problems arise from the practises: new crosses are often selected based on few, subjective opinions (Hampson et al. 2000). Internal quality, i.e. flavour and internal texture, is seldom evident externally, and is difficult to predict by visual control. To properly estimate the characteristics of various crosses and strains for example in a breeding program and their relevance to those, who consume the produce, sensory specialist's expertise is needed.

2.4.1 Appearance

The appearance of an apple like that of any fruit consists of size, shape, colour, and a lack of defects or decay (Kader & Barrett 2005). Appearance is regarded as a major pre-selection criterion when consumers are buying fruits and vegetables (Barrett et al. 2010; McCracken et al. 1994; Jaeger et al. 2003; Jaeger & MacFie 2001). According to Richardson-Harman et al. (1998), appearance, and especially skin colour, is more important in consumer judgments of

apple ripeness than tactile cues like firmness. In most cases, however, colour is not an appropriate measure to estimate freshness (Barrett et al. 2010).

European commission regulation EC No 85/2004 (2004) on apples focuses almost entirely on external attributes, while other apple characteristics are left unspecified. Apples are classified according to their size (classes Extra, I and II) and skin colour. Colour categories are A (Red), B (Mixed red colouring), C (Striped slightly coloured) and D (other). Furthermore, apples have to be clean, intact, sound and free from any foreign smell or taste.

The pioneer in the field of descriptive analysis of apples, Williams & Carter (1977), listed 40 attributes related to appearance, in addition to which, several of them were evaluated both internally and externally. Later studies have mostly used only few, if any appearance descriptors, probably because appearance varies greatly from apple to apple, perhaps more than other sensory properties

The background colour of apples is green, due to the fat soluble chlorophylls (Barrett et al. 2010). Other major pigments are carotenoids, anthocyanins, flavonoids and betalains. During ripening process, apples develop their typical colouring, for which process sunshine is essential (Iglesias et al. 2008). Phenolic compounds contribute to flavour and nutritional quality as well as appearance, and specifically, red colour, and are most prevalent in the skin (Defilippi et al. 2004). Phenolic compound metabolism appeared to be independent of ethylene action. Iglesias et al. (2008) showed that anthocyanin content had direct influence on the red skin colour of 'Gala' strains. Red skin is often valued in the breeding programs (Bonany et al. 2013; Iglesias et al. 2008).

The optimum size of apples is over 200 g in France (Herregods 1999). Also in Canada, the most preferred apple size was found to be nearly 200g, but older and female respondents preferred slightly smaller fruit size (Hampson & Quamme 2000). Some consumers link large size to good quality (Barrett et al. 2010). It is essential to remember that not all consumers want red or giant apples, and some even prefer small apples (Thybo et al. 2003). Consumers may also be quite indifferent towards the size of apples (Péneau et al. 2006). In Finland the typical size of domestic apple is often below 120 g.

In the literature there is evidence that appearance might not be that important to consumers (Jesionkowska et al. 2006, Mäkinen & Malkki 2004; Thybo et al. 2003). Different visual attributes appeal to different consumers and may even have niche markets (Hampson & Quamme 2000), as some consumers prefer green colour over red, or they may like bi-coloured apples. Consumers may make judgements on sweetness and sourness based on the colour (Cliff et al. 2014). Jaeger & MacFie (2001) suggested that consumers may dislike apples that are of different colour than the apples they usually eat.

Appearance is more important to less-frequent buyers and also to young people (Péneau et al. 2006). This observation suggests that as consumers become more experienced, "veterans", they are better able to pay attention to other details than appearance when making judgements on freshness and pleasantness, and consequently on whether to buy or not. This assumption gets support from Galmarini et al. (2013), who found that French were more knowledgeable on cultivars than Argentinians, and at the same time, they regarded appearance less important than Argentinians. However, those who consumed plentiful of apples in both countries resembled each other more in their appreciation pattern than their fellow-countrymen with less consumption.

2.4.2 Odour

Volatiles are responsible for the characteristic aroma of fruits (Kader & Barrett 2005). A compound has to be in a volatile state to be perceivable by the sense of smell, either orto- or retronasally. However, not all volatiles contribute to perceivable odours or flavours. Analysing and evaluating volatiles is challenging, as they are synthesised and segregated when the tissue structure brakes down either during biosynthesis and respiration, or mechanically during biting and mastication, aided by saliva (Salles et al. 2011). In addition, humans have only limited capacity to process and identify odour information (Lawless 1999).

Typical odours evaluated in apples are fruity and grassy odours, and odour or aroma intensity (Karlsen et al. 1999; Mehinagic et al. 2003; Symoneaux et al. 2012). Fruity odour is mainly caused by esters, and particularly by acetate esters (Aprea et al. 2012). Acetate esters contribute also to the odours "banana", "pear" and "apple" in apples. Sweet and sour (or acidic) odours are sometimes evaluated in descriptive analysis, although no sweet nor sour odour exists. The perception of an odour as sweet or sour is due to the learnt associations of certain odours to sour or sweet taste (Stevenson et al. 1995). In the case of apples, we probably learn early in the childhood that sweet tasting apples have a specific odour which we associate with "sweet odour", and likewise with sour apples. Off-odours such as soil or cellar (Mehinagic et al. 2003) or chemical odour (Karlsen et al. 1999) can also be evaluated.

Emission of volatiles is highly cultivar-specific (Soukoulis et al. 2012). The most abundant volatiles in 'Royal Gala' were observed to be esters and alcohols, and their production increased during ripening with concurrent increase in ethylene level (Moya-Leon et al. 2007). In 'Jonagold' apples, most abundant volatiles were alcohols, aldehydes and esters (Róth et al. 2007). The esters and alcohols contributed to several odours typical for apple, such as 'apple', 'plum', 'green', 'floral', 'fruity' and 'herbaceous' (Moya-Leon et al. 2007). Odour values, the relationship of volatile concentration with the corresponding threshold concentration, of several volatiles had high correlation with the rate of ethylene production (Moya-Leon et al. 2007) and consequently with the textural attributes. Apples stored in normal atmosphere

developed more perceived aroma than those stored in CA or treated with 1-MPC. These technologies restrict ethylene production, which reduces volatile production and ripening processes, and consequently, keeps the fruit structure firm (Konopacka & Płocharski 2004).

2.4.3 Taste and flavour

Typical terms used for flavour evaluation include sweetness, sourness, apple and fruit flavour, astringency and flavour intensity during chewing (Harker et al. 2002b; Karlsen et al. 1999; Kühn & Thybo 2001b). The perceived flavour of an apple is formed as a synthesis of sugars, acids and other components like tannins and volatile compounds during chewing and mastication in the mouth (Barrett et al. 2010; Harker et al. 2002b; Salles et al. 2011). Thus, for example perceived sweetness does not entirely correspond to the actual sugar content. When considering eating quality of apples, the relationship of sugars to total acids is often more informative than the sugar or acid contents separately (Anon. 2012).

The synthesis rate of flavour components increases, and their relative amounts change with maturation and ripening. Off-flavours may be produced trough enzymatic reactions forming free radicals (Barrett et al. 2010), especially during the later stages of ripening. Off-odours and -flavours appear typically towards the end storage life and include acetaldehydes, ethanol and reaction products from fungal activity (Kader 2008).

While ethylene action affects the texture of apples, it has been assumed that it does not have an effect on the accumulation of soluble solids, the sugar content indicator, or decreasing of sourness during ripening (Defilippi et al. 2004). Contrary to this, Defilippi et al. (2004), using an ethylene biosynthesis supressed apple strain, showed that the rate of starch conversion to sugars decreased with the suppression. This decrease was not observed in 1-MCP-treated fruits, indicating that the relationship between ethylene and sugar metabolism and the role of individual sugars is complicated. Likewise, organic acids reduction, which usually takes place during the later stages of ripening, was also blocked when using the ethylene-suppressed apple strain.

2.4.4 Texture

Texture and flavour during eating contribute greatly to consumer acceptance. Mealiness is regarded as a defect in the perceived quality of apples (Andani et al. 2001; Daillant-Spinnler et al. 1996; Jaeger et al. 1998; Kühn & Thybo 2001a), along with sogginess (Barrett et al. 2010). Mealiness impacts on the perception of flavours such as sweetness, as the cells of mealy apples do not break easily to release the fluids into the oral cavity, and thus prevent the

flavour components from coming in to contact with the sensory receptors in the mouth during mastication (Echeverria et al. 2008). Finns regarded juiciness as the most important textural property (Mäkinen & Malkki 2004; Malkki 2007), while Polish mentioned juiciness and firmness (Jesionkowska et al. 2006). Typical texture descriptors are firmness, crispiness, juiciness, mealiness, and skin toughness (Harker et al. 2002c; Thybo et al. 2005).

Parenchyma tissue is the major structural feature of fruit. It is a rigid texture with turgor pressure keeping the tissue matrix extended and maintaining crispiness (Szczesniak 1997). The integrity of the cellular connections has a great impact on crispiness and softness (Brummell 2006; Johnston et al. 2002). Crispiness is probably the most important feature of an apple of good quality. The term "crunchiness" has also been used to describe a texture typical to fresh apple flesh (Fillion & Kilcast 2002; Harker et al. 2002c; Symoneaux et al. 2012). Hampson et al. (2000) found that crispiness explained the major part of the differences in liking of apples, followed by juiciness and hardness, while skin toughness did not affect liking. Crispiness and crunchiness are often associated to the sound they produce during the first bite or chewing (Corollaro et al. 2013; Fillion & Kilcast 2002; Harker et al. 2002c; Ross 2009).

When translating a sensory descriptor to another language, it is sometimes difficult to come up with an exact translation. It seems that especially for some textural properties, multiple expressions have been used to describe the same concept, although small differences may lie in the exact meaning of the words. Harker et al. (2002c) had pulpiness, mealiness and flouriness as descriptors for a certain kind of texture. For "mealy", expressions "grainy" (Swahn et al. 2010) and "mushy" (Karlsen et al. 1999) have also been used. Andani et al. (2001) defined "mealiness" as "the sensation associated with floury, coarse, dry and soft texture in apples". While there may be variability across cultures towards different sensory properties of apples, Andani et al. (2001) showed that consumers from Spain, England, Denmark and Belgium perceived mealiness similarly.

2.4.5 Factors underlying sensory quality of apple

Although not actually a sensory property, freshness intertwines closely with several sensory attributes. Consumers associated apple freshness to crispiness, juiciness and firmness (Péneau et al. 2006; Péneau et al. 2007). Respondents considered mealy and sweet apples as less fresh, while sourness and aroma had minor relevance on freshness perception. It is possible that the deterioration of texture directed attention away from flavour, even when the flavour was somewhat deteriorated. Péneau et al. (2007) suggested that different sets of attributes influence the perceptions of freshness and liking. Consequently, freshness may be perceived through other attributes than what are used for liking perception.

Campbell et al. (2009), interviewing shoppers in New Zealand, observed that fruits were bought once or twice a week and 68% of the respondents had apples at home. Freshness experience is an important acceptance criterion with all foods, but especially with fruits and vegetables which seldom have best-before or use-by stamps, if not sold in packages. The best-date-information may be regarded as a guarantee of food quality (Wansink & Wright 2006). Without this information the shoppers have to use other means to draw conclusions on the freshness of the products. The effort to eat healthy by using fresh produce may cause excess waste in households (Koivupuro et al. 2012). This is probably because of the uncertainty of the storability and quality of the products.

Like freshness, origin is not a sensory property, but it is a popular theme especially in the research related to the field of economics. Origin refers usually either to the geographical origin, such as local, or to the production method, such as organic production. Wang et al. (2010) showed that the consumers who bought organic food valued product origin (local vs. non-local) over price, while for the non-buyers of organic produce, price was more important than origin. Consumers may sometimes see organic and local products as substitutable (Costanigro et al. 2014), although those who prefer local products do not necessary prefer organic produce (Denver & Jensen 2014). In fact, if evaluation is implemented without labels (blind), origin seldom has any positive effect on the acceptability that could be related to organic production method (Harker 2004). Moreover, postharvest management of crops in the retail sector may have greater impact on the quality than the preceding cultivation practices. Róth et al. (2007) did not find any effect of the production system on the amount of chemical compounds (including acids and sugars) in 'Jonagold' apples.

2.4.6 Effects of storage on sensory properties of apples

Understanding the biological processes associated with maturation and ripening is essential for optimising the quality of apples and the duration of storage (Johnston et al. 2002; Kader 2008). As already mentioned, maturity stage at harvest has a strong impact on the storability and consequently, sensory quality of apples. During storage, the crispy texture of a fresh apple gradually deteriorates and becomes soft, dry and mealy, at least partly induced by ethylene activity (Harker & Hallet 1992; Jonhston et al. 2002). The extent of softening and other textural changes varies greatly, depending on the cultivar, individual apple characteristics, harvest date and storage conditions (Brummell 2006; Costa et al. 2012; Galvez-Lopez et al. 2012; Harker & Hallet 1992).

Losses of water and turgor pressure are believed to be the major causes of fruit deterioration, bringing on losses in weight, appearance and texture (Johnston et al. 2002; Kader & Barrett 2005, Szczesniak 1997). Johnston et al. (2001) speculated that cultivars differ in their cell wall composition, which would cause the differences in their postharvest behaviour. There is

evidence that firmness remains good in CA storage for a long period of time, but the structure deteriorates rapidly after apples are removed to normal atmosphere (Konopacka & Płocharski 2002; Konopacka & Płocharski 2004).

2.5 Sensory studies on apple

Analytical sensory methods such as GDA offer an objective method for measuring cultivar characteristics, although high variability within each cultivar and apple makes training and eating quality measurement demanding (Dever et al. 1995; Hampson et al. 2000; Williams & Carter 1977). For example, the perceived flavour of an apple is formed as a synthesis of sugar and acid contents as well as other components such as tannins and volatile compounds during chewing and mastication in the mouth. Even the texture has an effect on the final perception.

As the postharvest apples consist of living tissue, they change with time (Hertog et al. 2007). Consequently, the differences in the perceived attribute intensities are larger than when evaluating factory-made products. Biological variance in the postharvest produce is due to 1) the heterogeneity of the samples or 2) the errors in the measurements. The heterogeneity is caused either by the differences in the biological age of the fruits or in the decay rates (De Ketelaere et al. 2006). For example, long pollination times may cause substantial age differences between individual fruits, which may even be enhanced by an uneven dispersion of sunlight on the trees.

2.5.1 Generic descriptive analysis

The best practices in performing GDA are thorough training of the panel accompanied with relevant descriptors (Lawless & Heymann 2010). The descriptors can be either created by the panellists as part of their training, or given to the panellists, but often a combination of these is used, i.e. some of the descriptors are suggested by the panellists while others are decided by the panel leader. The panel leader is also responsible for providing the references, preferable physical products or chemicals, but occasionally, if no physical reference is available written explanations are needed.

From time to time, non-trained panellists have been used for the descriptive analysis of apples (Andani et al. 2001; Moya-Leon et al. 2007). Hedonic ratings and analytical sensory attributes are sometimes evaluated by the same panel (e.g. Echeverria et al. 2003; Hampson et al. 2000; Iglesias et al. 2008), a practise not encouraged by the sensory specialists (Lawless & Heymann 2010).

Williams & Carter (1977) were among the first researchers to develop a sensory profiling method for apples, with extensive lexicon and detailed instructions for the assessment, followed by Watada et al. (1980), Dever et al. (1995) and Daillant-Spinnler et al. (1996). Jaeger and Harker with their colleagues have studied the sensory properties of apples extensively (e.g. Harker et al. 2002a; Harker et al. 2002b; Jaeger et al. 1998) followed by researchers in France (Mehinagic et al. 2004) and Spain (Echeverria et al. 2003). Sensory research on apples has been conducted in Northern Europe as well (Karlsen et al. 1999; Kühn & Thybo 2001a; Kühn & Thybo 2001b; Thybo et al. 2003; Thybo et al. 2005; Swahn et al. 2010). Finnish apples have not been an object of detailed sensory analysis before the present project, although some sensory and hedonic characteristics have been listed by Lento et al. (2010).

Descriptive analysis has been used for creating basic apple descriptions, comparison of cultivars and for studying sensory changes during storage with varying panel arrangements. For example, small postharvest teams with long practical horticultural experience (Brookfield et al. 2011), small trained panels (Billy et al. 2008; Galvez-Lopez et al. 2012) as well as larger trained panels (Billy et al. 2008; Corollaro et al. 2013; Mehinagic et al. 2004; Varela et al. 2008) have been used for assessing storage induced sensory changes. Even large untrained panels of up to 30-40 members (Echeverria et al. 2003; 2004; Moya-Leon et al. 2007) have been used.

Sensory studies have often been done with one, two or three cultivars (Andani et al. 2001; Billy et al. 2008; Jaeger et al. 1998; Mehinagic et al. 2004; Moya-Leon et al. 2007; Varela et al. 2008). Apart from Karlsen et al. (1999), Mehinagic et al. (2003), Thybo et al. (2005) and the fairly recent studies by Aprea et al. (2012) and Corollaro et al. (2013), only a few extensive studies have been conducted with descriptive analysis and a trained panel, using a broad range of cultivars as samples. Yet, it is generally admitted that cultivars differ greatly in their sensory properties, both at commercial maturity and during prolonged storage.

2.5.2 Consumer perception of apples

When discussing good quality of apples it is necessary to define what "good quality" of apples is for those who eat them. Attributes that are used for mapping the liking and preferences of the consumers should have relevance to them (Péneau et al. 2007). Agreeable texture and flavour are usually the most important properties (Daillant-Spinnler et al. 1996; Harker et al. 2003; Jaeger et al. 1998; McCracken et al. 1994). If the taste and texture are found acceptable, further purchases are probable, even if the appearance is not ideal. Harker et al. (2002a) showed that the consumers are able to remember differences in the texture of apples, but they are often forced to make their decisions of purchase based on the appearance (Jaeger et al. 2003).

Yet, the conception of what is acceptable varies across individuals, consumer groups and geographical regions. French respondents mentioned juicy, crunchy, sweet, tasty and firm most often when describing the expected quality of apples, while for the Argentineans; colour was the second most important quality parameter after juiciness (Galmarini et al. 2013). In the consumer vocabulary reported by Andani et al. (2001), sour and sweet were most often sited, followed by crispy, firm and mealy. Polish consumers valued flavour, juiciness, sweetness and firmness, while sourness, size and skin colour were not important to them (Jesionkowska et al. 2006). Results of a mail survey showed that flavour, freshness, maturity, juiciness and aroma were important properties for Finns, while colour and size had a minor importance (Mäkinen & Malkki 2004). Bonany et al. (2013) observed that in several European countries sweet apples were well liked, while in Germany, The Netherlands and Switzerland, more acidic apples were accepted. Cliff et al. (2014) found that the preference for sweet or sour apples depended on the ethnicity: the majority of the respondents of Asian origin preferred sweet over sour apples, while about half of those with European origin preferred sour apples.

Jaeger et al. (1998) emphasised that cultivar selection should be in line with the consumer preferences. Consumers can be classified into two distinct groups depending on their apple preferences: those who prefer sweet apples and those who like juicy acidic apples more (Harker et al. 2003). British and Danish respondents were segmented with internal preference mapping into two groups (Jaeger et al. 1998). The first liked hard, juicy and crisp texture, while in the second group, flavour was more important than texture in accordance with the findings by Daillant-Spinnler et al. (1996).

However, there is evidence that three segments might give a wider perspective of consumers' apple world. Tomala et al. (2009) segmented Polish apple consumers into three groups: group 1 liked all kinds of apples and group 2 liked firm, juicy and sour apples. The third group favoured sweet, flavourful and mature apples. Carbonell et al. (2008), studying Spanish apple consumers found three corresponding segments. The first group liked all attributes to be of medium intensity, the second favoured crispy, hard and sour apples and disliked mealy apples, while the third liked sweet, aromatic apples and accepted even some mealiness, which is usually regarded as a negative attribute (Andani et al. 2001; Jaeger et al. 1998). Cluster analysis on Swiss apple consumers revealed three similar segments as well (Egger et al. 2010).

2.5.3 Consumer vocabularies

Words collected from the participants of a consumer study can enlighten consumer attitudes and perceptions of the product in question. Free word association has been used to study consumer perception and attitudes towards local food (Roininen et al. 2006) and traditional

food products (Guerrero et al. 2010). Word association is an effective way to collect data in situations where mere words give the required information (Roininen et al. 2006). Interviews combined with suitable sorting tasks or questionnaires may reveal reason behind choices, preferences and attitudes (Roininen et al. 2004).

Repertory grid method (RGM) has been utilised to collect and analyse consumer descriptions of apples (Andani et al. 2001; Swahn et al. 2010) and other products (Costell et al. 2010; Fillion & Kilcast 2002). Fillion & Kilcast (2002) interviewed ten consumers following RGM to find out how they described textural similarities and differences in fruits and vegetables.

Symoneaux et al. (2012) used comment analysis to collect apple descriptions from French consumers after they had first rated their liking of the samples. When a descriptor was used as positive, it was coded with L (for example: L_Juicy), while negative expressions were coded with D. It was found out that the number of comments expressing like and dislike were related to the corresponding hedonic scores. Likewise, in a further study, descriptions were collected from the consumers in two countries, Argentina and France (Galmarini et al. 2013).

3 AIMS OF THE STUDY

The general aim of the study was to gain scientific knowledge on domestic apple characteristics and consumers' attitudes towards and perceptions of domestic apples, to help promoting apple production, consumption and marketing. This was achieved by the following sub-aims:

- Describing and measuring sensory characteristics of selected domestically grown apple cultivars (I, II) to construct profiles of the cultivars.

- Describing and measuring changes in the sensory characteristics of apples during prolonged storage in cold storage in normal atmosphere (II).

- Revealing the reasons behind repeated choices of apples made by Finnish apple consumers, and characterising consumers according to their appreciation of apple properties (III).

- Collecting vocabulary of the words and expressions that Finnish apple consumers relate to their most favourite apple to gain insight of the perceptions of apple users.

- Defining the monetary value of domestic apples to a group of Finnish consumers, and explaining their willingness to pay with pleasantness ratings of the apples and the amount of information available (IV).

4 MATERIALS AND METHODS

4.1 General description of the experiments

This thesis consist of two sub-studies describing cultivar characteristics organised in 2009 (I) and 2010 (II), and two investigating consumers' liking and appreciation of apples (III, IV) (**Table 2**). The consumer studies were organised in 2010 (III) and 2011 (IV), both having four cultivars, characterised with GDA of the same year. Some unpublished results are presented from the first consumer study in 2010 (III) and from the third year's GDA (2011).

Table 2. Apple cultivars included in the studies with DD5, origin and other details (Krannila & Paalo 2008; Tahvonen 2007). Maturation and storage times are estimates (Tahvonen 2007).

Cultivar	DD5 [a]	Breed	Origin of breed	Available in Finland	Maturation in storage/ weeks	Storage life/ weeks	Included in
Mid season							
Big Melba	1140	Melba x Huvitus	MTT	2003	2	3-4	I
Samo	1159	Melba x Huvitus	MTT	1981	2	1-2	I
Heta	1200	Lobo x Huvitus	MTT	1996	2	4-6	I, II
Pekka	1230	Lobo x Huvitus	MTT		2	4	I, II, III
Discovery *	1235	Worcester-Pearmain	England	1964	yes	6	I, II
Tobias	1235	Lobo x Huvitus	MTT	2003	2	6-8	I, II, IV
Summerred *	1260	Summerland **	Canada	1964	yes	8	I, II
Late season							
Red Atlas	1250	Winter St.Lawrence**	Canada	na	yes	4-6	I, II, III
Eva-Lotta	1260	Cortland x James Grieve	Sweden	1992	yes	8	I, II, III
Åkerö Hassel	1260	Åkerö	Sweden	na	2-4	8	I, II
Konsta	1264	Lobo x Antonovka	MTT	1997	4	4	I, II, IV
Lobo *	1302	MacIntosh **	Canada	1898	3-4	8	I, II, IV
Aroma *	1338	Ingrid Marie x Filippa	Sweden	na	4	6	I, II, III
Amorosa *	1338	Aroma	Sweden	na	4	6	I, IV
Y9330	1350	Wealthy **	MTT	no	long	8-12	I, II

a) Requirement for cumulative base temperature over 5°C during growing season.

* listed in EU regulation on apples (EC No 85/2004)

** free pollination

na) data not available no) not yet commercially available

All the cultivars in **Table 2** were analysed with GDA every year in 2009-2011, except the colour variants 'Aroma' and 'Amorosa', of which 'Aroma' was evaluated in 2009 and 2010 and 'Amorosa' in 2009 and 2011. Two of the cultivars ('Big Melba', 'Samo') were not part of Study II. In 2011, a total of 25 cultivars were analysed with GDA, while results of only four were reported in Study IV. The three-year-results of GDA of the mid and late season cultivars in **Table 2** with DD5 1200 or more are presented in Results. However, they are not reported in detail, as the main object is reporting cultivar profiles (I) and prolonged storage induced sensory changes (II) in these cultivars and not the effect of the harvest year, which will be discussed in the future.

4.2 Sample selection and organisation in the experiments

Cultivars representing a wide range of traditional and new, as well as dessert and processing apples were selected for the study. Some of the cultivars were known to have not-so-good sensory quality. The purpose was to gain a broad perspective of the sensory properties prevailing in the domestic cultivars. The main focus was in the mid and late season cultivars, as they have a slightly longer storage life than early season cultivars, and therefore have commercial potential. The cultivars were harvested in the orchards at the MTT research station in Piikkiö and surrounding areas in South-Western Finland during August–September. The apples were harvested and stored according to the standard horticultural practises. Depending on the cultivar, it took two to four weeks in the storage before the cultivar reached commercial maturity. Calculation of the storage times in this study started when the commercial maturity was reached.

4.2.1 Storage and transportation of the samples

The harvested apples were kept in the cold storage of the research orchard (+3°C, RH 80–92%) and monitored for maturity using horticultural methods, such as starch iodine testing and visual inspection (Brookfield et al. 1997; Tahvonen 2007). Before the first evaluation, the cultivars were transferred to the cold storage (+4°C) at the Department of Food and Environmental Sciences, University of Helsinki, where they were kept for a maximum time of three weeks, depending on the schedule of the evaluations.

4.2.2 Presentation of the samples in the experiments

Apples were evaluated at room temperature and the panellists rinsed their mouths with water between the samples. Evaluation order was randomised in all experiments to balance it for position and carry over effects. All samples were coded with three-digit numbers, except in the first consumer study (III), where cultivar names were visible for the participants to see.

4.2.3 Organisation of the generic descriptive analysis (I-IV)

Each cultivar was evaluated with GDA at two stages of maturity: at the point when it had reached commercial maturity (evaluation point A) and 2-3 weeks later (evaluation point B). Between the two time points the apples were kept in the cold storage at the university, except the cultivars of the storage study in 2010 (II), which were transported to the department shortly before each storage point. All the apples were at normal commercial maturity in the points A and B. Profile results were calculated as the mean of the storage points A and B. As the maturity stage of the apples does not stay constant but keeps progressing over the days and weeks, taking average of the intensities in the points A and B was a compromise to simulate "commercial maturity continuum". The evaluations were done in the sensory laboratory at the university.

4.2.4 Organisation of the storage experiment (II)

Each cultivar was evaluated with GDA for the first time when it had reached full commercial maturity (storage point A) and then following a storage plan (**Figure 5**). The storage points B-D were 3–4 weeks apart, and the time from point D to point E was 6 weeks (two cultivars). At the storage points A and B, the cultivar 'Heta' was accompanied by three early season cultivars, which were not part of the storage experiment.
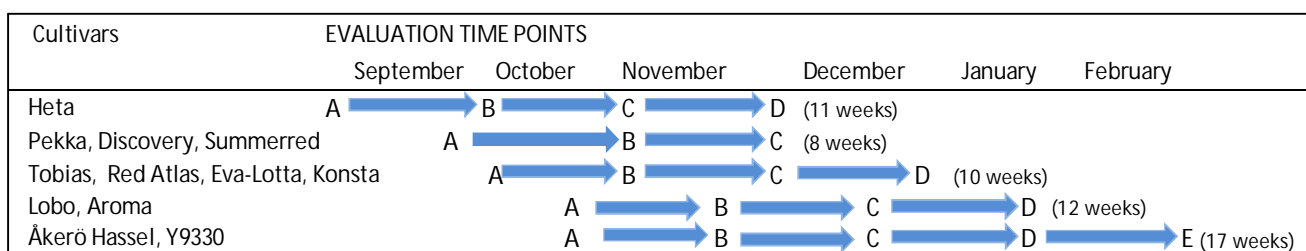
Figure 5. Evaluation schedule of the cultivars in the storage study (II). Each storage point was 3-4 weeks apart, except between points D and E, time was 6 weeks.

4.2.5 Cultivars in the consumer studies (III, IV)

Four cultivars were selected for both consumer studies in 2010 (III) and 2011 (IV) (**Table 2**, **Table 3**). The cultivars were chosen to vary especially in crispiness, sourness and sweetness. The decision was based on the GDA results of the previous year and availability of the cultivars. In addition, they had to be at an ideal maturity stage during the experimental phase, which lasted about two weeks in both cases. The sensory profiles of the cultivars were determined by a trained panel, following the principles described in Study I. To avoid bias in the 2010 study (III), where cultivar names were visible, the market leader ('Lobo') was not chosen for Study III.

4.3 Evaluation principles

The study protocol followed the ethical guidelines approved by the ethical committee of the Viikki Campus, University of Helsinki. A written informed consent was obtained from each participant before entering either the trained or consumer panel. A trained panellist was not accepted to either of the consumer panels. Likewise, a consumer panel participant could take part to only one of them. All panellists were volunteers from Helsinki metropolitan area. The members of the trained panels were students and employees at the Department. Participants in the consumer studies ate apples regularly. Summary of the participants, samples and attributes, measures and statistical methods is in **Table 3**.

4.4 Procedure for the generic descriptive analysis

Sixteen cultivars were analysed with GDA during three subsequent harvest years (2009-2011) following the principles by Lawless & Heymann (2010). The lexicon with references and evaluation method was created at the beginning of the first year's analyses concurrently with the training (**Table 4**). Each of the following years' work started with training sessions. Minor modifications were done during later years. Additional five attributes (outside and inside browning, fermented flavour and odour, mouldy odour) were included to describe the storage induced changes in 2010 (II), determined based on pre-testing during the previous season.

Table 3. Participants, number of samples and measures, and statistical methods in the studies I-IV.

Study	Participants	Samples	Measures and scales	Statistical methods
I	**Trained sensory panel** n=12 (11F 1M), 22-55 y n=11 (10F 1M), 22-55 y	7 mid season cultivars 8 late season cultivars	Intensity of 20 attributes; 0='not at all', 10='very'	Means, SD, repeated ANOVA, correlation, regression analysis, PCA
II	**Trained sensory panel** n=14 (12F 2M), 22-56 y	12 mid & late season cultivars [b]	Intensity of 15 attributes; 0='not at all', 10='very' [d]	Means, SD, repeated ANOVA, t-test, cluster analysis, PCA
III	**Trained sensory panel** n=14 (12F 2M), 22-56 y	4 mid & late season cultivars [b]	Intensity of 8 attributes; 0='not at all', 10='very' [d]	Means, SD, repeated ANOVA
III	**Consumer panel** n=108 (77F 31M), 19-65 y, mean age 45 y	4 mid & late season cultivars	Degree of liking; 1='like not at all', 7='like very much', preferred intenstiy of 6 sensory properties of apples; semantic scale 1–7 (Not red–Red, Not green–Green, Soft–Firm, Meal –Crispy, Not sweet–Sweet, Not sour–Sour), demographic data, use frequency, CSI (Steenkamp & Baumgartner 1995)	Means, SD, repeated ANOVA, t-test, number of selections, cluster analysis logistic regression analysis
	Consumer panel n=122 (88F 33M, 1 NA [a]), 19-65 y, mean age 46 y		Open ended descriptions of the most preferred apple (ideal apple)	Number and type of descriptions
IV	**Trained sensory panel** n=13 (11F 2M), 24-57 y	4 mid & late season cultivars [c]	Intensity of 13 attributes; 0='not at all', 10='very' [e]	Means, SD
IV	**Consumer panel** Consumer panel n=118 (95F 23M), 19-79 y, mean age 37 y	4 mid & late season cultivars	Pleasantness; 1='extremely unpleasant', 9='extremely pleasant' willingness to pay (euros/kg), demographic data, use frequency	Means, SD, repeated ANOVA, t-test, correlation, regression analysis

a) NA gender information not available
b) evaluated among 16 cultivars in 2010
c) evaluated among 25 cultivars in 2011, 21 of which are not presented in detail in this thesis
d) evaluated among 23 attributes in 2010
e) evaluated among 17 attributes in 2011

Table 4. The attributes, evaluation techniques and references in the generic descriptive analysis in 2009-2011. The attribute codes are used in Figures 8-11.

Attribute	Attr. in Finnish	Code	Evaluation [a) b)]	Reference	Analysed	Included in
Appearance	*Ulkonäkö*					
green	*vihreä*	A-green	visually from ten apples	paints NCS S0520-G70Y -> NCS S2070-G30Y [c)]	2009-2011	I, III, IV
red	*punainen*	A-red	- " -	paints NCS S0530-Y70R -> NCS S4050-Y90R [c)]	2009-2011	I, III, IV
relative area of red	*punaisen määrä*	A-%red	- " -	na	2009-2011	I
amount of skin wax	*kuoren vahaisuus*	A-wax	manually by touching the skin	compared to the waxiness of *cv. Transparente blanche*	2009-2011	I, IV
Odour	*Haju*					
intensity	*voimakas*	O-intens	from a newly cut apple surface	na	2009-2011	I, II
grassy	*ruohomainen*	O-grass	- " -	fresh parsley leaves with fresh apple slices [d)]	2009-2011	I
sour	*hapan*		- " -	na	2009	I
sweet	*makea*		- " -	na	2009	I
fruity	*hedelmäinen*	O-fruit	- " -	canned fruit cocktail in juice	2009-2011	I, II, IV
Texture	*Rakenne*					
hard	*kova*	T-hard	cutting with knife	boiled carrot -> raw carrot	2009-2011	I, II, IV
crispy	*rapea*	T-crisp	biting with front teeth	boiled carrot -> celery	2009-2011	I-IV
mealy	*jauhoinen*	T-mealy	after continued chewing: soft, dry and mealy texture	boiled carrot -> boiled mealy Rosamunda potato	2009-2011	I-IV
juicy	*mehukas*	T-juicy	amount of tasty liquid in the mouth during chewing	boiled mealy Rosamunda potato -> mature pear	2009-2011	I-IV
soggy	*vetinen*		amount of tasteless, waterlike liquid in the mouth	applepear (soggy)	2009-2010	I, II
tough peel	*kuoren sitkeys*	T-peel	amount of peel in the mouth after 8 chews with molar teeth	na	2009-2011	I, IV
Flavour, taste	*Maku*					
intensity	*voimakas*	F-intens	during chewing	na	2009-2011	I, II, IV
sour	*hapan*	F-sour	- " -	< 0.5 % L(-)-malic acid in Muksu apple jam (sour) [e)]	2009-2011	I-IV
sweet	*makea*	F-sweet	- " -	< 10 % sucrose in Muksu apple jam (sweet) [e)]	2009-2011	I-IV
astringent	*astringoiva*	F-astr	- " -	<0.15 % tannic acid in in Muksu apple jam (astringent) [e)]	2009-2011	I, II
diversity	*monipuolinen*	F-divers	during chewing: aromatic, spicy, flowery and perfumed notes	na	2009-2011	I-IV
Deterioration	*Pilaantuminen*					
outside browning	*tummuminen pinnalta*		estimated visually from ten apples	discussions	2010	
inside browning	*tummuminen sisältä*		- " -	series of photographs	2010	
mouldy odour	*maamainen haju*		from a newly cut apple surface	<moss in soil	2010	II
fermented odour	*käynyt haju*		- " -	<sparkling wine Old Rosie Cloydy Scrumpy, 7.3% vol.	2010	II
fermented flavour	*käynyt maku*		during chewing	<cider Ecusson Grand Cidre, Pur jus-Brut, 5.5 % vol	2010	II

a) The appearance was evaluated from 10 intact apples of a cultivar. For the other attributes, each panellist had two apples of a cultivar, which s/he cut into pieces during evaluation.

b) The scale ranged from "not at all" (0) to "very" (10) for each attribute, except for the relative area of red and browning, for which the range was 0–100 %.

c) Teknos paint catalogue, www.teknos.fi and www.teknos.co.uk/?pageID=H2892 [accessed 2009-12-01].

d) reference was *cis*-3-hexen-1-ol (15 µl/10 g paraffin wax) in 2009

e) "Muksu" is commercial, unsweetened apple jam for babys. In 2009, malic asid and sucrose were mixed in water, tannic acid in apple juice.

na) no reference available. Guidelines for evaluation were set by discussion.

4.4.1 Developing the lexicon (I)

Development of the lexicon was initiated in 2009 with four early season cultivars ('Pirja', 'Vuokko', 'Transparente Blanche', 'Petteri'). After familiarising themselves with the cultivars at home use and collecting suggestions for the attributes, the panel met in three sessions and agreed on 20 attributes and their references (**Table 4**). Bitter taste was not included in the final lexicon, because the panel did not consider it a relevant attribute in the context of mature domestic apples. Originally the panel wanted to include size and shape descriptors to the lexicon. During the process they were left out, because both are quite well described in horticultural publications (e.g. Krannila & Paalo 2008; Tahvonen 2007). In addition, the apples in the study were mainly size-sorted. Information gained with these attributes would have been minimal. In general, domestic apples are fairly small in size, with some exceptions. For example in Study I, mean size of the apples ranged from 87 to 153 g, depending on the cultivar.

4.4.2 Evaluation method (I-IV)

The evaluation method of GDA was tested and fine-tuned with several early season apples in 2009. Before the evaluation of each subsequent batch, an additional training session was arranged, where the properties of the apples in the new batch were discussed and references studied to be sure that the attributes were relevant throughout the apple spectrum. Likewise, in the two subsequent years, training started with the early season apples.

The attributes were rated for intensity on a graphic, unstructured scale extended beyond the fixed endpoints. The scale ranged from 'not at all' (0) to 'very' (10) for each attribute, except for the degrees of redness and browning (both outside and inside), for which the range was 0–100% (converted to 0–10). The evaluations were performed in separate booths at individual speed using Fizz sensory analysis software (version 2.20 Biosystems, Couternon, France).

The appearance attributes were evaluated at the beginning of each session from a set of ten apples per cultivar in a separate space. After appearance evaluation, odour, texture and flavour were evaluated in individual booths under red light to disguise the differences in the appearance. At this phase, each sample consisted of two unpeeled, whole apples, to avoid discolouration, off-flavours and tacky surface caused by the peeling and cutting. Each panellist had a plastic cutting board and a knife, and was instructed to cut a slice from one side of the apple and not to cut to the core, to avoid the atypical texture and off-flavours from the seeds and core. The odour attributes where evaluated from the freshly cut surface.

The evaluations were carried out twice during the storage of mature mid and late season cultivars, 2–3 weeks apart (evaluation points A and B). Each evaluation was replicated, midseason apples in 2009 (I) twice in two consecutive days (4 replicates) and in all other cases twice during one day (2 replicates). The number of samples varied from 2 to 5 in a session, depending on the harvesting schedule and maturation of the apples.

4.5 Methods in the consumer studies

4.5.1 Hedonic ratings and repeated choices (III)

In the week preceding the experiment phase, the participants (n=108) filled in a background questionnaire including demographic data, apple-eating habits and other questions. During the next week, they visited the testing area three times (Mon–Wed–Fri) to rate the four cultivars using a 7-point scale (1='like not at all', 7='like very much') (**Figure 6**). The data were collected in two locations in Helsinki, in an office centre with municipal and state offices and at the University of Helsinki in the vicinity of catering area.

The unpeeled apples, provided with cultivar names, were served as sliced on a large paper plate divided into four sections by a marking pen. Each cultivar was also laid out in a large open plastic box with cultivar name and a colour picture on it for visual inspection. Each time, the ratings of liking were to be based on all the information available: the appearance of the cultivars and tasting of the slices. After the evaluation each participant chose three fruits from one cultivar to take home to eat.
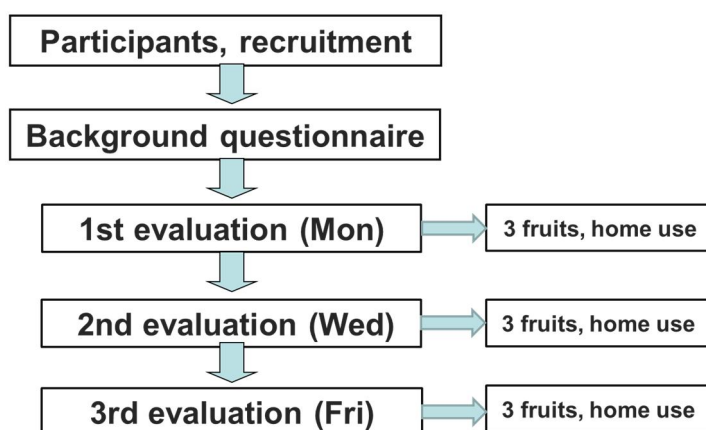
Figure 6. Flowchart of the study on repeated liking and choices (III).

4.5.2 Hedonic ratings and willingness to pay (IV)

Each participant (n=118) took part in one session, comprising of eight phases with three auction rounds (**Figure 7**). The data were collected at the University of Helsinki, Viikki Campus in a class room. The procedure followed the BDM-method (Becker et al. 1964), where the respondent submits a bid (i.e. WTP) for each product in each round and the winners are determined after the rounds.
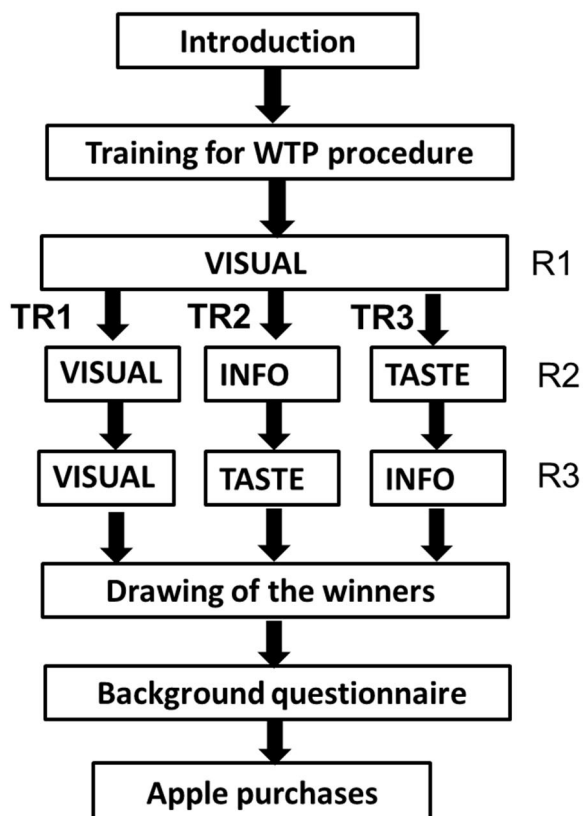
Figure 7. Flowchart of the auction sessions (IV). Each participant was randomly assigned to one of the three treatments (TR1, TR2, TR3) which consisted of three evaluation and auction rounds (R1-R3). R1 was similar in all three sessions.

Three treatments (TR1, TR2, TR3) were used, and each session was devoted to one treatment. Each treatment had three rounds (R1, R2, R3). Participants looked at the four samples, tasted them or they were given written information of them, according to the treatment and round. The cultivars were on display unpeeled in open bowls (visual and information phases) or given in four separate closed paper bags (tasting).

In each round, two types of responses were elicited: Pleasantness of the cultivars was rated on a nine-point scale (1='extremely unpleasant', 9='extremely pleasant') and willingness to

pay (WTP) was expressed as the maximum amount of money in euros each participant was willing to pay for a kilogram of apples (euro/kg). One paper ballot for the ratings of pleasantness and WTP was used in each round, collected after each round.

Before the first round, a short presentation was given about the procedure and a training session conducted with a snack bar. Then the three-round-session commenced, followed by the drawing of winners. One of the three rounds was randomly selected to be the binding round. Likewise, one of the samples was randomly chosen to be the binding product. Finally, the price was randomly drawn from a price distribution ranging from 1.00 to 6.00 euro/kg with an increment of 20 cents. The respondent purchased apples, if her/his bid was greater than the randomly drawn price in the round that was the binding round.

4.5.3 Ideal apple descriptions

On the first page of the background questionnaire for Study III, respondents were asked to describe their most favourite apple in their own words (ideal apple descriptions). On the second page, they rated six sensory attributes of apples on 7-point semantic scales anchored at each end (ideal apple questionnaire) followed by the demographic data as described in 4.5.1. The rated ideal attributes (Mealy – Crispy, Not sweet – Sweet, Not red – Red, Soft – Firm, Not green – Green, Not sour – Sour) were chosen based on the descriptors used in other consumer studies (e.g. Andani et al. 2001, Jesionkowska et al. 2006) and to have connection with the attributes in GDA performed in this study. Of the 122 respondents who started the study (III), 14 were not able to complete all the steps for example due to work related absences, and were not included in Study III.

4.6 Statistical methods

All statistical analyses were performed with SPSS 16.0 or PASW 18.0 (SPSS 16.0.2, SPSS Inc. and PASW Statistics 18.0.2). Unscrambler (versions 9.8 and X10.1) was used for Principal component analysis (PCA) (Camo SA, Trondheim, Norway). All statistical effects and interactions were studied at the significance level p=0.05. The data were analysed with the procedures as described in the original publications (**I-IV**) and in **Table 3**.

5 RESULTS

5.1 Cultivar profiles (I)

Simplified profiles were constructed for 15 cultivars (**I**). Of the originally analysed 20 attributes chosen during the panel training, nine were extracted to be used for the simplified profiles. Extraction was performed based on the ability of the descriptors to differentiate the cultivars, based on the results of repeated measures ANOVA and linear regression analysis. The descriptors selected needed also to reveal the typical and important features of the cultivars. For example, flavour intensity was found to be the function of flavour diversity, sourness and odour intensity (R^2=0.47). Neither odour and flavour intensities nor grassy odour differentiated most of the cultivars and were removed. The percentage of red area had high correlation with red intensity in most of the cultivars so the area of red was excluded. Colour is a crucial feature in regulations, and textural attributes crispiness and mealiness are the major quality attributes for consumers. Thus, these attributes were included into the simplified lexicon. Simplified profiles are easier to utilise when describing cultivar characteristics to the wider audience. Examples of the profiles for six cultivars are shown in **Figure 8**.
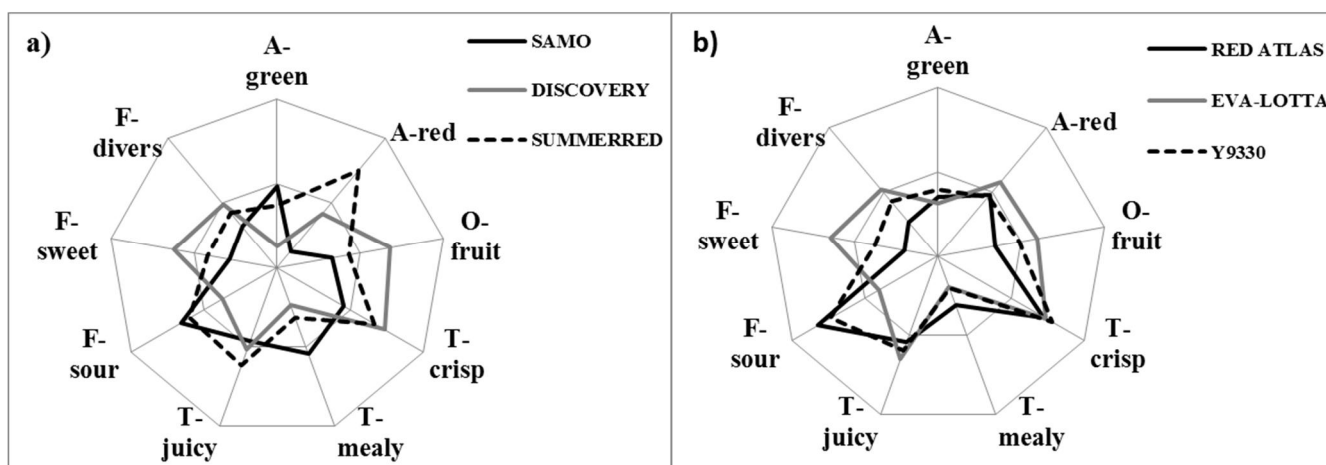
Figure 8. Simplified cultivar profiles of six cultivars, n=12x4x2 (8a) and n=11x2x2 (8b). Scale from 0 ('not at all') to 10 ('very'). A=appearance, O=odour, T=texture and F=flavour attributes, codes are explained in detail in Table 4.

For professional use, wider profiles consisting of up to 20 attributes are available (I). The descriptors differentiated the majority of the cultivars so that the profiles are unique in one or more attributes. 'Pekka' was the sweetest cultivar, followed by 'Eva-Lotta' and 'Discovery', while 'Red Atlas' and 'Y9330' had the highest intensity of sourness. 'Samo' was the mealiest, followed by 'Pekka'. Grassy odour was strongest in 'Samoa' as well, while fruity odour was strongest in 'Discovery'. The differences between the cultivars in the texture properties mealy, crispy and juicy were smaller than in the flavours sweet and sour (F-value 9.6-15.1 for the former and 18.2-46.1 for the latter).

There were also similarities between the cultivars. Since 'Heta', 'Pekka' and 'Tobias' are all crosses of 'Lobo' x 'Huvitus', it is interesting to compare them in the same graph with the mother cultivar 'Lobo' (**Figure 9**). 'Pekka' was the sweetest and reddest and the least sour and astringent of them. Fruity odour was the strongest in 'Pekka'. 'Heta' and 'Tobias' were fairly similar with each other as they differed only in colour and waxiness. 'Lobo' resembled its breedings in many aspects.
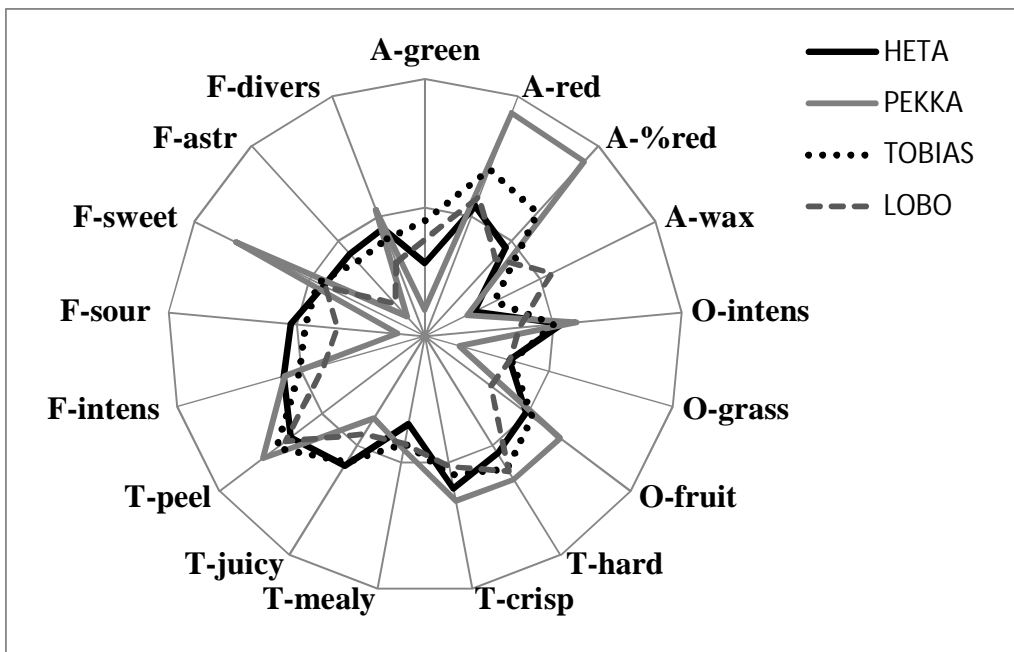
Figure 9. Cultivar profiles with 17 attributes for three crosses of 'Lobo' x 'Huvitus' in 2009 (I), n=12x4x2 for 'Heta', 'Pekka' and 'Tobias', and n=11x2x2 for 'Lobo'. Scale from 0 ('not at all') to 10 ('very'). A=appearance, O=odour, T=texture and F=flavour attributes, codes and scales are explained in detail in Table 4.

5.2 Profiles of the three years

Attribute intensities in the twelve cultivars (with DD5 1200 or over) evaluated during the three subsequent harvest years (2009-2011) are visualised with a PCA graph based on the correlations (**Figure 10**). The graph describes the sensory space of the samples and attributes. The first and second principal components (PC) explained 55% of the variance, while the third explained 10%. The graph is interpreted as follows: a straight line is drawn through the origin towards the attribute of interest. Other lines are drawn to the first line from the cultivars at right angles. The distance between the cultivars in the line describes the relative intensity of the attribute in question in the cultivars. For example, the intensity of juiciness in 'Heta' was more similar in the second and third year than in the first. We also notice that juiciness and crispiness of 'Y9330' (on the right hand side above axis) were quite similar in all the three years, although their intensity was slightly stronger in the first year (2009).
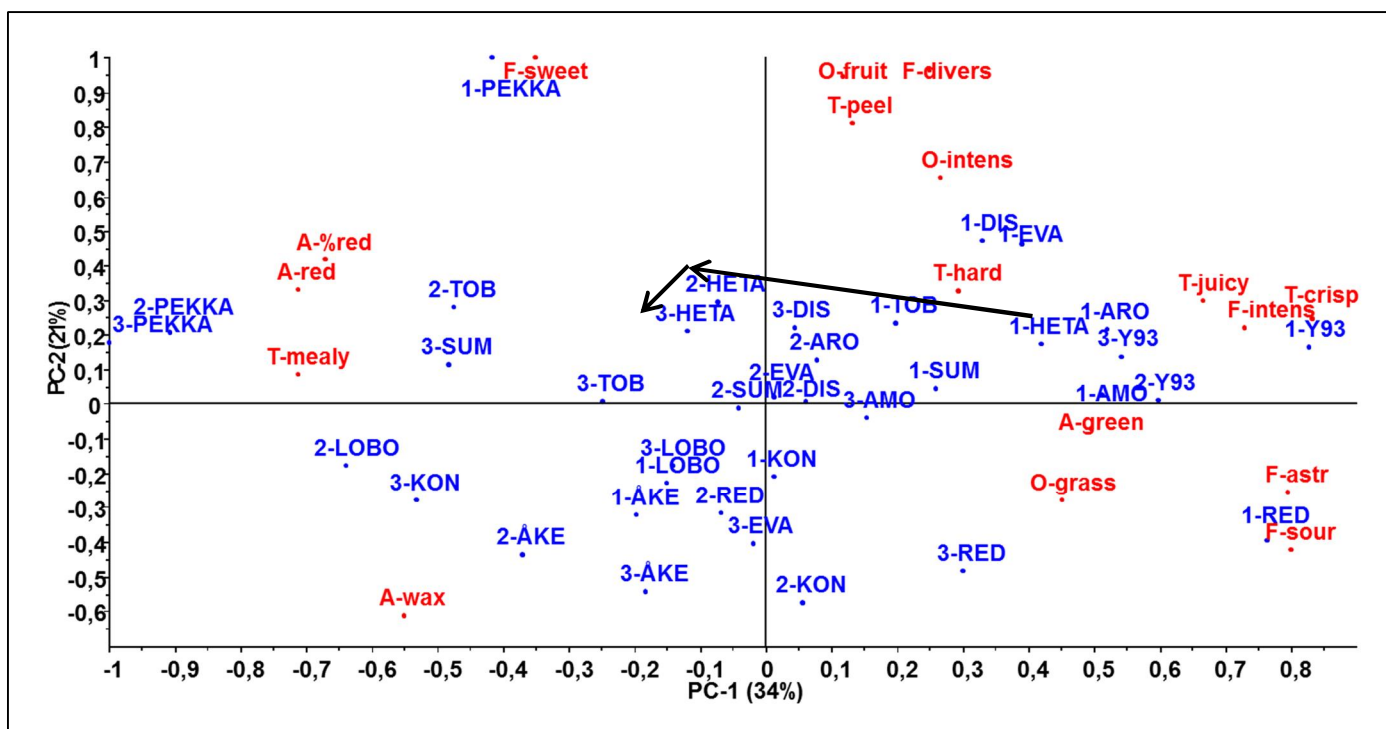
Figure 10. Principal component analysis of the cultivars and the sensory attributes during three harvest years, 1 (2009), 2 (2010) and 3 (2011), visualised with the first and second principal components. The progress of 'Heta' over the years is illustrated with black arrows. Cultivar abbreviations: PEK = 'Pekka', DIS = 'Discovery', TOB = 'Tobias', SUM = 'Summerred', RED = 'Red Atlas', EVA = 'Eva-Lotta', ÅKE = 'Åkerö Hassel', KON = 'Konsta', ARO = 'Aroma', AMO = 'Amorosa', Y93 = 'Y9330'. The numbers 1-3 in front of the cultivar name or abbreviation refer to the successive years of the evaluation. A = appearance, O = odour, T = texture, F = flavour attributes, codes are explained in detail in Table 4.

The PCA graph shows that while the differences between the harvest years were occasionally substantial, most of the cultivars of the years 1, 2 and 3 were grouped together, and thus kept their basic characteristics throughout these years. For example, while 'Pekka' was somewhat sweeter in the first year (1) than in the following two years (2, 3) its sweet, mealy and red disposition remained the same. Likewise, although 'Heta' and 'Discovery' were juicier in the first year than in the next two years their nature was all the time juicier and crispier than that of 'Pekka'.

The attributes that are grouped together in the graph have correlation with each other, such as juiciness and crispiness, and fruity odour and diverse flavour. Similarly, the cultivars that are grouped near each other are more similar than those that are situated far away. However, the PCA graph does not reveal absolute magnitudes. The first PC illustrates continuum "mealy-juicy" and the second "sour-sweet", while sourness and sweetness loaded also on the first PC. The graph suggests that mealy texture is related to red skin colour. On the lower left hand side of the PCA graph, grassy odour and flavours astringent and sour are grouped near green colour. Sour and astringent flavours are presented on the first PC at the same level with juicy and crispy texture, suggesting that all these attributes are linked together.

The profile graph of the cultivars 'Aroma' and 'Amorosa' shows that they were similar during the three years (**Figure 11**) and really are variants of the same cultivar, in spite of the effect of the harvest year (**Figure 10**). Both were crispy and medium sweet and medium sour. The intensity of sweetness and sourness appears to have been slightly higher in 2009 than during the two following years.
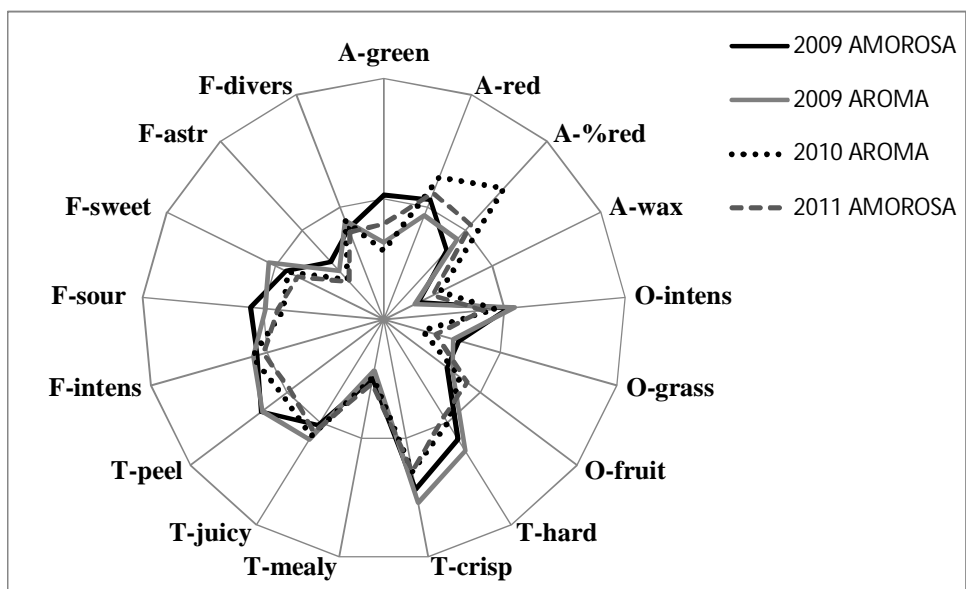
Figure 11. Cultivar profiles with 17 attributes for colour variants 'Aroma' and 'Amorosa', n(2009)= 11x2x2, n(2010)=14x2x2, n(2011)=13x2x2 for each cultivar. Scale from 0 ('not at all') to 10 ('very'). A=appearance, O=odour, T=texture and F=flavour attributes, codes are explained in detail in Table 4.

5.3 The effect of storage on the attribute intensities (II)

Attribute intensities in the cultivars evaluated during the prolonged storage were visualised with a PCA graph (**II**). The graph showed distinctly that during the storage, the cultivars moved towards mealier and less crispy texture, while the extent of this tendency varied. Flavour diversity and sourness diminished, but in other flavour attributes as well as in odour attributes, the changes were less convergent. In most cultivars, sweetness remained at the same level or diminished slightly, but in 'Y9330', sweetness increased towards the end of the storage. Some cultivars developed fermented odour or flavour during the prolonged storage, especially 'Heta', 'Tobias' and 'Eva-Lotta'.

In **Figure 12** the development of sourness and mealiness during the storage is demonstrated with four cultivars. During the 70-80 days of storage (four storage points, A-D), sourness diminished statistically significantly only in 'Lobo' (1.4), while in 'Heta', 'Red Atlas' and 'Aroma', the drop was between 1.1 and 1.2 units (in a scale of 0 to 10). The pattern of mealiness increase depended on the cultivar. In 'Heta' and 'Lobo' the increase was 3.0-3.1 while in 'Red Atlas' and 'Aroma' it was much smaller, 1.3-1.5 units (in a scale of 0 to 10). The differences were significant for all except 'Red Atlas'.
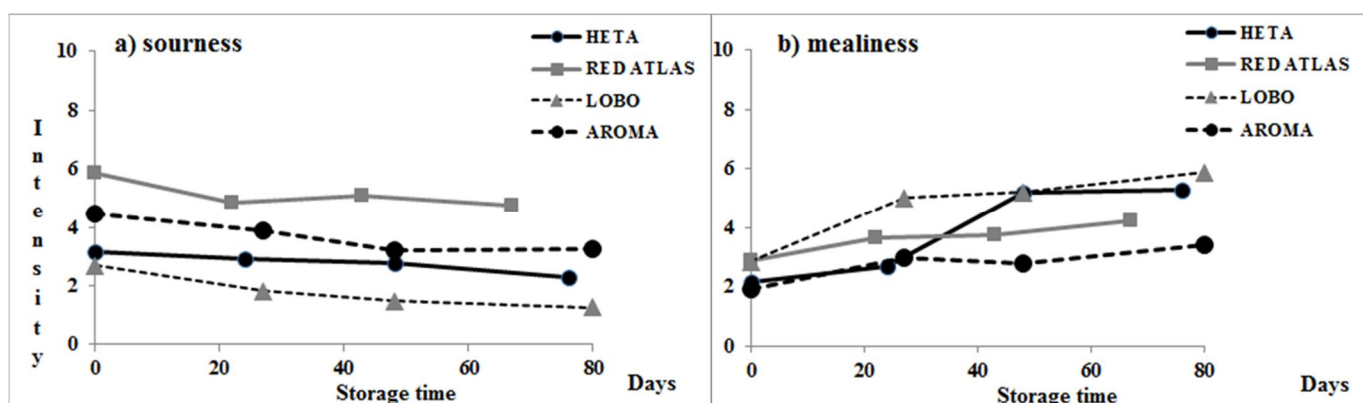
Figure 12. Development of a) sourness and b) mealiness of selected cultivars during storage, n=14x2 in each storage point. SEM was 0.2-0.4 in sourness and 0.3-0.5 in mealiness.

Cluster analysis on the 12 cultivars in the storage study showed that the cultivars changed their typical characteristics over time (**Table 5**). The analysis performed on the major texture and flavour intensities of the cultivars at each storage point (3-5 points) revealed four distinctive apple clusters (CL). They were visualised with a PCA graph in Study II, where each CL was situated approximately in one quarter of the sensory space, and were named accordingly: CL1(juicy & sour), CL3(juicy & sweet), CL2 (mealy & sour), and CL4(mealy & sweet).

Apples in CL1 (3 apples) were crispy, juicy, astringent, sour, low in sweetness and high in flavour intensity. In CL2 (17 apples), the apples were less crispy than in CL1. They were medium juicy but somewhat mealy and less sour than in CL1. Apples in CL3 (16 apples) were medium crispy, juicy, medium sour and their sweetness and flavour diversity was higher than in CL1 and CL2. Apples in CL4 (11 apples) were low in sourness and flavour diversity and high in sweetness, and they had mealy and medium crispy texture.

Table 5. Movement of the cultivars between the cluster types during the storage. Letters A-E refer to the storage points, which were 3-4 weeks apart, except between the points D-E the time was 6 weeks.

CLUSTER:	CL 1	CL 2	CL 3	CL 4
CULTIVAR	juicy & sour	mealy & sour	juicy & sweet	mealy & sweet
Heta			A, B ⟶	C, D
Pekka				A, B, C
Discovery		B, C ⟵	A	
Tobias			A ⟶	B, C, D
Summerred		C ⟵	A, B	
Red Atlas		A, B, C, D		
Eva-Lotta		D ⟵	A, B, C	
Åkerö Hassel		A, B, C, D, E		
Konsta	A ⟶	B, C, D		
Lobo			A ⟶	B, C, D
Aroma		D ⟵	A, B, C	
Y-9330	A, B ⟶		C, D, E	

Apples in the different storage points moved between the clusters, except 'Red Atlas' and 'Åkerö Hassel' in CL2 (mealy & sour) and 'Pekka' in CL4(mealy & sweet), which remained in their original cluster throughout the storage time. Especially the apples in CL3(juicy & sweet) moved to other clusters: 'Heta', 'Tobias' and 'Lobo' moved to CL4(mealy & sweet) where 'Pekka' already was. 'Discovery', 'Summerred', 'Eva-Lotta' and 'Aroma' moved all to CL2(mealy & sour). No cultivar remained in CL1(juicy & sour) after the second storage point.

5.4 Repeated choices (III)

'Aroma' was the best liked and most often chosen cultivar for home use (145 out of 324 times). 'Eva-Lotta', 'Pekka' and 'Red Atlas' were chosen 75, 70 and 34 times, respectively. The cultivars were chosen in various combinations: 24 respondents chose the same cultivar each time, while 28 chose always a different cultivar. Respondents with high hedonic flexibility (HedFlex, III, Mustonen et al. 2007) were more prone to change the cultivar

between the sessions. They also chose the sweet cultivars ('Eva-Lotta' and 'Pekka') more often than the respondents with low HedFlex, although the latter group liked them more.

Mean liking of 'Aroma' was 5.3 (SD ± 1.2), while 'Red Atlas' was the least liked with the mean of 4.0 (SD ± 1.4) (over three sessions). The differences between mean likings were relatively small compared to the times they were chosen (III). For example in the third time, 'Aroma' and 'Eva-Lotta' were equally liked and 'Pekka' slightly less liked, but the cultivars were chosen 37, 26 and 30 times, respectively. The distribution of the liking scores shows that although 'Red Atlas' was the least liked, it was well liked by some respondents and similarly, some respondents did not like the generally well liked cultivars 'Aroma' and 'Eva-Lotta' (**Table 6**).

Table 6. The frequency of the liking scores for each cultivar, sessions pooled (n=108x3). Scale from 1 ('like not at all') to 7 ('like very much').

Cultivar	Frequency of liking scores						
	1	**2**	**3**	**4**	**5**	**6**	**7**
Aroma	1	11	30	35	79	98	70
Eva-Lotta	1	11	35	60	96	85	36
Pekka	4	26	58	63	79	61	33
Red Atlas	19	36	65	74	71	41	18

When the mean liking is calculated based on what cultivar was chosen, the differences between the ratings are clear (**Table 7**). In fact, those who chose a certain cultivar rated their liking of that cultivar on average between 5.6 and 5.9. The difference between the liking of the chosen and other cultivars was highest for Red Atlas (1.4 - 2.3) and smallest for Aroma (0.6 - 1.3), which both are sour cultivars, although Aroma has also sweetness.

Table 7. Mean liking of the cultivars according to the cultivar selected for home use (n=108, over the three rounds). The cultivar selected is in the first column, and liking of all cultivars by those who selected the cultivar in question are in the rows. The liking of the selected cultivar is in bold. Scale from 1 ('like not at all') to 7 ('like very much').

Cultivar selected	Aroma	Eva-Lotta liking	Pekka	Red Atlas
Aroma	**5.9**	4.7	4.1	4.2
Eva-Lotta	4.9	**5.8**	4.4	3.7
Pekka	4.6	4.5	**5.8**	3.3
Red Atlas	5.3	5.1	4.1	**5.6**

The respondents with low HedFlex (n=67) rated their liking of 'Eva-Lotta' higher in the first two sessions than those with high HedFlex (n=41), while in the third session, liking of 'Eva-Lotta' in the HedFlex high group rose significantly. The opposite happened with 'Aroma', as during the first two sessions, ratings of liking were similar in both groups while in the third, liking decreased in the HedFlex high group.

Using logistic regression analysis it was shown that when choosing apples, respondents made the decision to choose a cultivar based on not only the cultivar that was liked but also on those which were not liked (III). For example, the choice of 'Aroma' in the first session could be explained with liking of 'Aroma' and disliking 'Eva-Lotta' and 'Pekka' with a success rate of 79% as follows:

$$\text{Choice(Aroma)} = 1.0(\text{LikeAroma}) - 0.5(\text{LikePekka}) - 0.4(\text{LikeEva-Lotta}) - 1.2$$

In two cases belonging to a cluster had a role in selection, and in three cases HedFlex was a meaningful variable in the logistic regression models.

5.5 Ideal apple characteristics (III)

The ratings on the ideal apple questionnaire showed that crispy apples were better liked than mealy ones (mean 5.6 in a scale of 1='mealy' to 7='crispy'). In general, the participants preferred red apples slightly more than green ones (4.8 vs. 3.8 for red and green intensity), and sweet apples over sour (5.1 vs. 3.7). Clustering revealed three distinct segments (**Figure 13**):
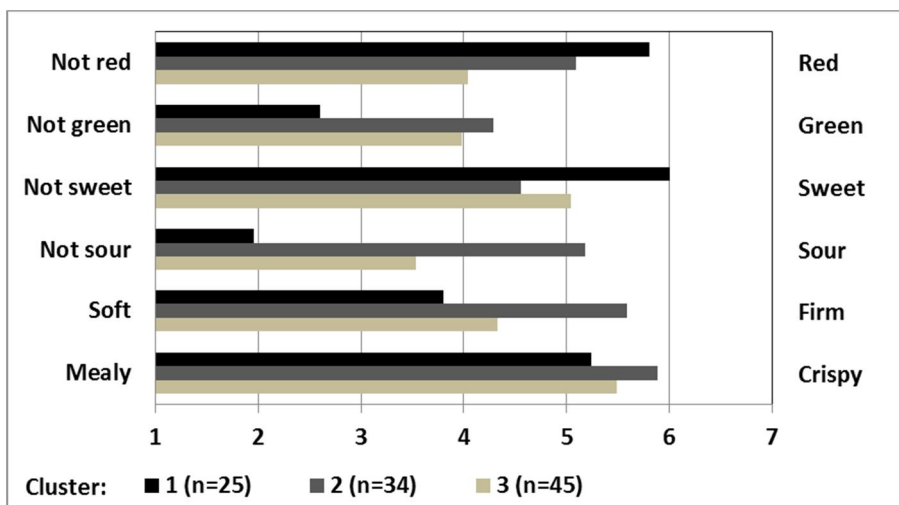

Figure 13. Consumer segments of 'sweet', 'sour' and 'sweet-sour' clusters, based on k-means cluster analysis of the preferred intensity of six ideal apple descriptors (n=104).

- CL1 (n=25) preferred sweet, soft and red apples, and disliked sourness and green apples, and was named CL1(sweet)

- CL2 (n=34) preferred sour, crisp and firm apples, and was named CL2(sour)

- C3 (n=45) preferred medium sour and medium sweet, and was named CL3(sweet & sour)

Respondents in CL1(sweet) were willing to pay slightly more for their apples and they did not like tough peel. Those in CL2(sour) were more likely to have families with children. While respondents in all of the clusters preferred crispy apples, those with high HedFlex preferred crispier apples more than those with low HedFlex.

Calculating the mean liking of the cultivars based on the respondent's CL revealed differences in liking. Respondents in both CL1(sweet) and CL3(sweet & sour) liked all the cultivars except 'Red Atlas', while those in CL2(sour) liked 'Aroma' most and 'Pekka' least (III). Inspecting liking and the number of cultivars chosen in each session separately showed that the liking of 'Eva-Lotta' changed between the sessions more than the liking of other cultivars (**Table 8**). The degree of liking of 'Pekka' and 'Red Atlas' differed between the clusters, while 'Aroma' was equally liked across the clusters. The liking of 'Eva-Lotta' was the lowest in CL2(sour) in the first session, but in the later sessions, the differences in the liking between the cluster were small.

Table 8. The mean liking of the cultivars with SD and how many times each cultivar was chosen for home use in each session according to the cluster (n=104 in each subsequent session). Scale from 1 ('like not at all') to 7 ('like very much').

Cultivar	Session	CL1 sweet (n=25)			CL2 sour (n=34)			CL3 sweet&sour (n=45)		
		Times chosen	Liking (SD)	*	Times chosen	Liking (SD)		Times chosen	Liking (SD)	
Aroma	**1st**	9	5.5 (1.1)	a	22	5.4 (1.7)		22	5.5 (1.3)	
	2nd	14	5.0 (1.5)	ab	15	5.3 (1.3)		22	5.4 (1.4)	
	3rd	5	4.8 (1.2)	b	19	5.5 (1.4)		11	5.3 (1.4)	
Eva-Lotta	**1st**	4	5.1 (1.3)	a A	6	4.4 (1.1)	b B	10	5.1 (1.5)	ab A
	2nd	6	4.5 (1.3)	b	8	4.9 (1.1)	a	12	4.8 (1.4)	ab
	3rd	8	5.3 (1.2)	a	5	5.1 (1.1)	a	12	5.4 (1.4)	a
Pekka	**1st**	9	4.7 (1.6)	AB	3	4.1 (1.2)	B	11	4.8 (1.4)	b A
	2nd	5	4.4 (1.8)	AB	5	4.0 (1.4)	B	7	4.7 (1.5)	b A
	3rd	10	4.8 (1.8)	A	4	4.0 (1.3)	B	16	5.3 (1.2)	a A
Red Atlas	**1st**	3	3.8 (1.6)		3	4.4 (1.3)		2	3.8 (1.5)	
	2nd	0	3.4 (1.7)	B	6	4.3 (1.4)	A	4	4.0 (1.5)	AB
	3rd	2	3.5 (1.5)	B	6	4.6 (1.3)	A	6	4.0 (1.8)	AB

* denotes the statistical difference (p<0.05); small letters between sessions within the cultivar and cluster (vertical); capital letters between clusters within each cultivar and session (horisontal), based on LSD.

5.6 Hedonic ratings and willingness to pay (IV)

Mean hedonic rating over all the cultivars, rounds and sessions was 6.6 (SD ± 1.7), and mean price in the bids was 2.36 euro/kg (SD ± 0.91). In TR1, the differences between the cultivars and rounds were small. In the other treatments, the means of pleasantness and WTP were quite similar for three cultivars ('Amorosa', 'Lobo', 'Tobias'), whereas they were lower for the sour cultivar 'Konsta' (**Figure 14**).
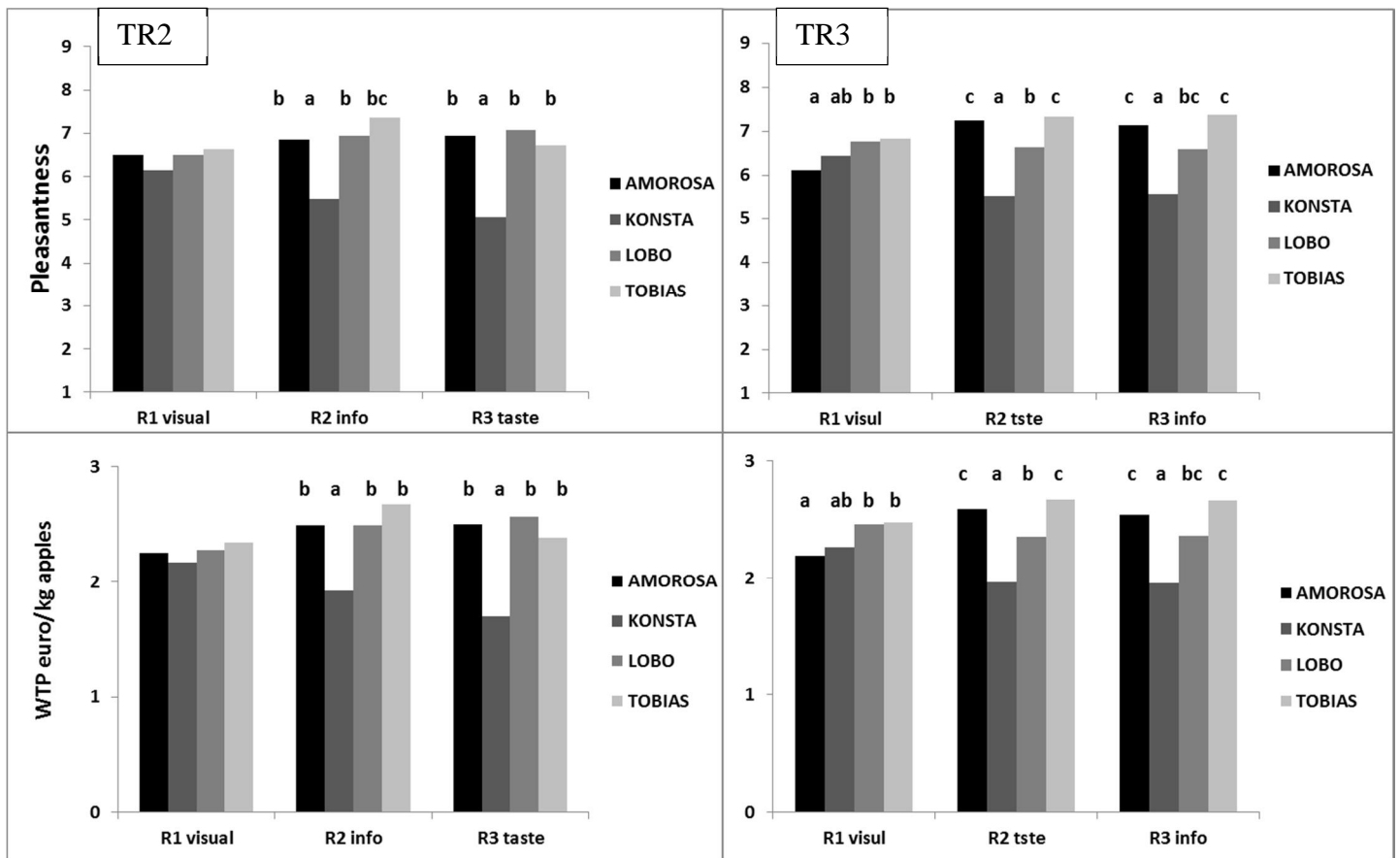
Figure 14. Ratings of pleasantness and willingness to pay (WTP) for each cultivar in different rounds (R) of treatments 2 and 3 (TR2 and TR3). TR2 on the left, TR3 on the right. Pleasantness ratings at the top row, WTP ratings at the bottom. For evaluation of pleasantness and making their decision on WTP, respondents in TR2 used cues visual-information-taste, and in TR3 cues visual-taste-information, in each of the three rounds, respectively, n(TR1)=25, n(TR2)=44 and n(TR3)=49. The scale for pleasantness was 1 ('extremely unpleasant') to 9 ('extremely pleasant'). Standard error was 0.19-0.31 for pleasantness and 0.11-0.18 for WTP. The small letters above the columns denote the statistical difference (p<0.05) in the ratings of pleasantness and WTP between the cultivars.

The use frequency of domestic apples affected WTP considerably (**IV**). The participants who reported eating domestic apples more than once a week were called heavy users of domestic apples, and the others were called light users. For the apples in general, corresponding groups were formed. The heavy users of domestic apples were willing to pay on average over 0.5 euro/kg more for the apples than the light users. This was seen in all cultivars and the difference was largest for 'Lobo' (0.74 euro/kg). Most of the differences in the pleasantness were also significant but less dramatic. No differences were observed in the ratings of pleasantness or WTP between the user groups of apples in general.

When WTP was studied by the treatment and round, it was found out that the heavy users of domestic apples were willing to pay from 0.26 to 1.13 euro/kg more than the light users, and the majority of the differences were significant (**Table 9**). Most of the differences in the pleasantness were small and below the level of significance. Again, no differences were observed with the user groups of imported apples in either of the measures.

Table 9. Mean difference in the amount of money in euros that heavy and light users of domestic apples were willing to pay in treatments 2 and 3.

Round	Treatment 2 (n=45) [a]			Treatment 3 (n=49) [b]		
	VISUAL	INFO	TASTE	VISUAL	TASTE	INFO
	Price difference (euro/kg) [c]			Price difference (euro/kg)		
AMOROSA	0.26	0.61 *	0.73 *	0.70 **	0.50 *	0.44 *
KONSTA	0.74 **	0.38	0.69 *	0.27	0.55 *	0.71 **
LOBO	1.13 ***	1.11 ***	0.95 **	0.45 (*)	0.40 (*)	0.39
TOBIAS	0.96 **	0.92 **	0.76 *	0.54 *	0.33	0.57 *

a) In TR2, n(heavy)=26, n(light)=18

b) In TR3, n(heavy)=34, n(light)=15

c) level of significance: *** $p<0.001$; ** $P<0.01$; * $p<0.05$, (*) $p<0.1$

Linear regression analysis performed on the pooled cultivar data showed that pleasantness explained 38-55% of the WTP depending on the round and treatment. When the rated pleasantness increased by one unit, WTP increased by 0.31 to 0.45 euro/kg. The differences in the explanation rates and models were substantial when the analysis was performed on each cultivar and treatment separately.

5.7 Ideal apple descriptions

Participants (n=122) in the repeated choice study (III) used 525 expressions to describe their most favourite domestic apple. The number of descriptions per person varied between two and ten, and likewise their length. The shortest ones consisted of two words, while the longest were several lines long and included detailed explanations. Texture was mentioned 145 and flavour 118 times (**Table 10**).

Table 10. The 525 descriptions of ideal apple collected during the repeated choices study (III) (n=122).

DESCRIPTOR		Mentioned, times
FLAVOUR		118
sweet	64	
sour & acid & tart	54	
TEXTURE		145
crispy & crunchy	23	
juicy	52	
mealy	21	
hard & firm & soft	49	
HEDONIC & TEXTURAL FLAVOUR		29
APPEARANCE		139
peel & waxiness	23	
intact & smooth surface	25	
colour & beautiful	55	
size & shape	36	
ODOUR		10
FRESH & CLEAN & ORGANIC		65
fresh & ripe	19	
brisk	30	
clean & safe & organic	16	
ORIGIN & CULTIVAR		19

Sweetness was mentioned 64 times, of which only 5 were negative. Sour and related expressions were used 54 times, of which 11 were in negative form (e.g. "no acidity") and 18 expressed a preference for medium to low intensity of the attribute ("not too tart"). Nine different Finnish words were used to describe sour entity, while sweetness was described with only two words, one of which was used only once ("sugary").

Of the textural attributes, juiciness was most often cited and always positively. "Not-soggy" was mentioned once. Both crispy & crunchy and hard & firm entities were described with seven different Finnish words. All respondents preferred crispy and crunchy apples, while 16 respondents wanted low or medium intensity of firmness. All textural entities contained several onomatopoetic or dialect words. Part of the crispy & crunchy expressions contained sound induced during biting or chewing (e.g. "rouskuva" in Finninsh) while some contained mouth-feel ("narskahtava").

A specific colour was mentioned 34 times, in addition to which "beautiful colour" was cited several times. Six respondents were of the opinion that the colour does not matter. Twenty respondents mentioned red or reddish colour, but several of them liked also other colours or bi-coloured apples. Three respondents did not mind about the size, while five wanted large and four small apples.

Almost twenty respondents explained that they want the peel to be soft and not to get it stuck between their teeth, while eight said they enjoyed that the domestic apples can be eaten unpeeled and even unwashed. Respondents' comments on eating peels reflect their knowledge of the healthiness of apples and peels specifically. Traditionally, domestic apples have been eaten unpeeled, while imported apples have been eaten peeled. Recently the Finnish Food Safety Authority Evira published instructions that imported apples can likewise be eaten unpeeled if washed properly. However, it may take some time before these practices change.

Numerous different expression were used to describe apples that are clean, without worms or apple scab, free of toxic chemicals, organic, domestic, and freshly picked. Thirty respondents used a Finnish word "raikas" which does not have an exact translation into English. Its partial meaning is fresh, but here the word brisk is used in translation, because fresh is reserved for freshly picked apple, contrary to old ("tuore" in Finnish). "Raikas" contains meanings of atmosphere, emotion and feeling, such as "breezy wind", "refreshing juice" and "fresh ideas". The gustation of menthol is "raikas" as well. Four respondents mentioned coolness of apples.

6 DISCUSSION

This thesis consists of two sub-studies describing cultivar characteristics (I, II), two which investigate consumers' liking and appreciation of apples (III, IV), and some previously unreported data, which together form an overview picture of the Finnish apple world as far as sensory and consumer aspects are concerned.

The profiles as such present valuable scientific information also for the future research on domestic apples, because no such dataset has been available before in Finland. Likewise, storage-induced sensory changes in domestic apples have never been reported before. The cultivars varied considerably in their characteristics and in the way these characteristics changed during the storage. Some of the cultivars showed a promising capacity to retain their eating quality longer than what has previously thought to be possible.

Consumer studies emphasised the importance of versatile selection of domestic apples available in the stores, and informative labelling of the cultivars. In the multiphase choice study, initial liking was not very good at explaining later liking and choices. The vocabulary describing an ideal apple showed that Finnish apple consumers do not have only a single preferred apple type, but apples with different appearance, flavor and texture will be needed also in the future. Domestic apples are valued for their cleanliness, safety and freshness. The frequent eaters of domestic apples may be more willing to pay higher prices for domestic apples. This suggests that promoting domestic apple consumption eventually promotes also the prices paid for them.

6.1 Apple profiles

Results from both Study I and Study II revealed two attribute entities, one consisting of two major flavour attributes, sour and sweet, and the other consisting of three closely related textural attributes, juicy, mealy and crispy. These have a close-knit relationship with consumer quality shown by the previous literature (e.g. Andani et al. 2001; Harker et al. 2008; Jaeger et al. 1998) and the results presented in this thesis (III), IV.

The attributes formed a sensory space of three dimensions explaining 69% of the total variance in Study I. The dimensions were labelled "sour-sweet", "mealy-juicy" and "crispy-mealy". The odour and flavour attributes formed sour-sweet continuum on the first PC and the textural attributes loaded mainly on the second and third. In addition, the appearance characteristics red and green were presented by the first and second dimensions. The sensory space of the attributes was in accordance with the literature. Kühn & Thybo (2001b) identified similar sour-sweet and mealy-crispy axes. Attributes ranging from "sweet, red" to

"sour, green" on the first PC and from "juicy, crispy" to "granular, floury" on the second PC in Jaeger et al. (1998) and Andani et al. (2001) are in accordance with these findings.

In spite of the minor differences in the characteristics of 'Lobo' and 'Aroma', the results of Study I were similar to Karlsen et al. (1999): 'Lobo' was mealier and 'Aroma' juicier and sweeter of the two. Likewise, the first PC with sour-sweet-axis resembled the PC by Karlsen et al. (1999). However, while in Study II there were texture loadings on the second and third PCs as mealy-juicy and crispy-mealy, Karlsen et al. (1999) had mushy-juicy-crispy continuum on the second PC.

The low correlations between most of the descriptors used in GDA support the representativeness of the lexicon developed. The detailed sensory descriptions were further worked to construct simplified cultivar profiles to help horticultural and marketing personnel in communicating cultivar characteristics to the general public. Until this study, the material available about the sensory quality of domestic apples has contained many hedonic descriptions and thus, is not very objective or balanced.

When extracting the attributes into the simplified profiles, it was made sure that the attributes selected had relevance to the consumers (Lawless & Heymann 2010; Péneau et al. 2007) or some other important reason to be included. The simplified profiles had many similarities with the consumer vocabularies in Andani et al. (2001) and Swahn et al. (2010), and with the descriptions collected by Galmarini et al. (2013) and Symoneaux et al. (2012).

Appropriate crispiness, juiciness and not-too-high mealiness are universal indicators of good quality of apples, although some variation in the optimal intensities occur. Both the sweetness and sourness are relevant to the consumer quality, and their balanced relationship is also meaningful to the consumers (Anon. 2012). In Northern Europe, sourness is usually better accepted than elsewhere (Alavoine et al. 1990; Bonany et al. 2013; Harker et al. 2003), but individual differences are large. During the data collection for Study III and Study IV, numerous respondents exclaimed spontaneously at some point either "I love sour apples" or "I do not like sour apples".

The colours red and green were included to the simplified profiles as appearance affects choice (Barrett et al. 2010; Cliff et al. 2014; Jaeger & MacFie 2001; Jaeger et al. 2003; Jaeger et al. 1998). The consumers use colour to recognise their favourite apple and to estimate ripeness (Richardson-Harman et al. 1998). Colour has an important part in the EU regulations on apples (European Commission 2004). Red and green were difficult to assess consistently due to high variation in the sample material, but in spite of this, the colours differentiated most of the cultivars.

Grassy odour was a distinctive feature of some cultivars like 'Samo', but it was not included in the simplified profiles as it did not differentiate between most of the cultivars. Astringency

had a high positive loading on the second PC, and it differentiated the cultivars, but it was not included in the profiles as the concept is not easily understood by a layman. The same applies to soggy texture, as it is difficult to assess without training.

Lento et al. (2010) performed a brief analysis on 16 domestic cultivars, including 'Samo', 'Heta', 'Konsta', 'Lobo', 'Red Atlas' and 'Tobias' but the descriptions differed from the findings in Study I. For example, they concluded that 'Samo' had mild odour, and the flavour was sweet and sour, while the results of Study I showed that grassy odour was the strongest in 'Samo' among all the 15 cultivars analysed, in addition to which odour intensity was quite strong and flavour sweetness low. However, hard and firm texture of 'Lobo' and 'Red Atlas', and mealiness of 'Konsta' and 'Tobias' reported by Lento et al. (2010) were in accordance with the findings in Studies I and II. As the main aim in Lento et al. (2010) was to examine apple wine, the apple descriptions were only approximate and brief, and resembled more the traditional descriptions in the horticultural literature than the profiles obtained through descriptive analysis. In addition, the panel size was 3-4, and no details were reported on the methods, references or attribute intensities.

The PCA graph of the three-years-study showed similar textural patterns to Study I, although in this case, mealy-juicy-continuum loaded on the first PC. Sour-sweet continuum loaded on the first and second PCs. This may indicate that on average the textural properties were more stable during the three years while the flavour attributes had higher variability and multidimensional features over the years, which is supported by the literature (e.g. Bizjak et al. 2013; Łata & Tomala 2007). Summer 2010 was exceptionally hot and dry and it can be assumed that the apple trees had to reduce producing flavour compounds in the fruit to ensure survival, and consequently, the flavour profiles of the apples may have suffered. The weather in summer 2011 was not ideal either, as it was exceptionally humid, causing high rate of plant diseases. These climate factors may explain the differences between the first (2009) and the two subsequent years. However, more detailed research would be needed in the future to find out the exact effects of weather conditions on the sensory characteristics of the apples.

6.2 Storage-induced changes

The aim of Study II was to gain a wide perspective on the storability of domestic cultivars and the quality and magnitude of the changes in their sensory properties, when apples are stored in normal atmosphere. The storage conditions were selected to resemble the conditions typical in small and medium size storages, as there are very few CA storages available.

The changes in the intensities of the odour and flavour attributes were minor (although often noticeable) compared to the changes in the texture. As Harker et al. (2003) pointed out the customers should be informed about the typical product characteristics. Climacteric fruits

such as apples continue ripening in the cold storage and consequently, their properties do change. Even having a CA storage facility available does not solve all deterioration issues (Konopacka & Płocharski 2002; Konopacka & Płocharski 2004).

The effects of storage were most apparent in the textural properties, but the magnitude of the changes depended on the cultivar. Changes in the crispiness and juiciness ratings were quite uniform across the cultivars, but the differences in mealiness development were substantial between the cultivars. Mealiness increase may have been due to the cell wall, cell-to-cell and other parenchyma tissue characteristics (Brummel 2006; Echeverria et al. 2008; Harker & Hallet 1992; Johnston et al. 2002). The differences in the parenchyma structure may explain why the texture of some cultivars ('Tobias', 'Konsta', 'Lobo') became mealy quite soon, while others ('Red Atlas', 'Aroma', 'Y9330') had only minor changes in their mealiness during the first three months of storage. Even at the end of 17 weeks' storage, mealiness of the new cross 'Y9330' was lower than in several cultivars much earlier (e.g. 'Lobo', 'Tobias'), when these still were of commercial quality.

Storage induced mealiness has been associated with off-flavours (Andani et al. 2001; Jaeger et al. 1998). In Study II, the off-odours and -flavours developed in some cultivars ('Tobias') were associated with mealiness increase on the first and third PC. Off-odours and -flavours are a typical sign of the end of flavour life, and include accumulated acetaldehydes and ethanol as well as reaction products from fungi or other sources (Kader 2008). Off-odours and -flavours were not strong in Study II because only edible apples were evaluated, but clearly observable. Especially 'Eva-Lotta' suffered from fermented odour and flavour. Occasionally off-odours and –flavours were noticed also in Study I and during GDA in 2011, although these were not evaluated as attributes.

All cultivars in Study II except one ('Red Atlas') had differences in the intensities of one or more flavour attributes during the storage. Five cultivars retained their sweetness intensity throughout the storage, while sweetness decreased in five. The sweetness of 'Eva Lotta' decreased notably towards the end of the storage. It is possible that the reduction was caused by the biological processes consuming sugars and producing fermented off-odours and -flavours in this cultivar, which may be the reason for the sharp decrease in the sweetness and flavour diversity intensities.

'Y9330' increased considerably in the sweetness and flavour diversity intensities concurrently with a temperate decrease in sourness, suggesting that its eating quality may even improve during the storage. At the same time, moderate mealiness developed only towards the end of the long storage, and thus, the cultivar showed high potential for becoming an important late harvest commercial cultivar. 'Aroma' kept surprisingly well during the three months of storage, much longer than the six weeks that have traditionally assumed to be the limit of the storage life of 'Aroma'. It is a pity that the storage plan had not

included 'Aroma' into the batch of extended storage of 17 weeks along with 'Y9330' and 'Åkerö Hassel'.

Textural changes in the apples during the storage have been studied instrumentally and apples categorised based on these measurements (Billy et al. 2008, Costa et al. 2012; Mehinagic et al. 2004), but before Study II, apples have not been clustered based on the sensory changes defined by detailed sensory analysis. Performing cluster analysis on the twelve apples in each storage point revealed four clusters, CL1(juicy & sour), CL2(mealy & sour), CL3(juicy & sweet) and CL4(mealy & sweet). At the end of the storage phase, no apples remained in CL1(juicy & sour), and 'Y9330' was the only one remaining in CL3(juicy & sweet). Cultivars that moved between CL1(juicy & sour), CL2(mealy & sour) and CL3(juicy & sweet) maintained conventional commercial quality better than those that where in CL4(mealy & sweet) or moved there.

However, not all the apples in CL4 were overripe or too mealy, as some consumers prefer sweet and soft fruits (Harker et al. 2003). This is confirmed by the findings in this study: although 'Pekka' was not the most popular cultivar in Study III, it was not the least liked, either. During the three sessions in Study III, liking of 'Pekka' even increased among some of the respondents. In the ideal apple descriptions collected during Study III, 10% of the respondents described preferring soft or not-too-firm apples. It is possible that the elderly or people having teeth or mastication troubles prefer soft fruits (e.g. Roininen et al. 2004). The effect of age was not observed in this study, probably because all the participants were healthy and still at working age.

The poor performance of 'Lobo' during storage was a surprise because it is widely cultivated in Finland (Tike 2009). The off-flavour development in 'Eva-Lotta' was also a disappointment. Currently 'Eva-Lotta' is cultivated only in Aland Islands but it would have been a good candidate to be cultivated in the mainland Finland because it was well liked in Study III. Planting new apple trees is a big investment for the orchards, and the type of the trees determine the success and income level of the farm for over a dozen of years. Of course, long storage life of apples is only one fact among many considerations, but obviously one of the most important determinants of the future.

Although most of the storage induced changes are minor during normal commercial cycle, they are predominantly negative from the consumer point of view. It is worthwhile to know the typical tendencies of each cultivar to be able to communicate their characteristic features to the consumers. However, how relevant the changes are during normal commercial cycle, and are there consumer segments that are more sensitive to the quality deterioration than other segments need yet to be investigated.

6.3 Liking and choices

Study III showed that Finnish apple consumers can be clustered into three distinct groups in accordance with the literature (Carbonell et al. 2008, Egger et al. 2010; Tomala et al. 2009). The group that preferred sweet apples was the smallest and the group favouring sweet&sour was the largest. Clustering was not reasonable in Study IV as the treatments had already divided the respondents into sub-groups, and respondents especially in the smallest, "sweet", cluster would have been too few to make firm conclusions on their behaviour in the treatments. Further research should aim at having a simpler procedure to learn more about the perceived pleasantness and WTP and their relationship in different consumer groups.

'Aroma', the most conventional of the cultivars in Study III, was the best liked and most popular option in all three sessions. In general, the higher the liking of a cultivar was, the more often it was chosen for home use. During second and third sessions, as the other cultivars became more familiar, they were chosen more frequently. Not surprisingly, having high HedFlex increased the likelihood to change cultivars between sessions and to choose cultivars other than the most familiar option, 'Aroma'.

The results of the ideal apple questionnaire showed that crispy apples were more liked than mealy, as mealiness is a typical negative quality attribute of apples (Jaeger et al. 1998), and one of the major problems with traditional domestic varieties during storage, as was seen in Study II. Crispiness was an equally appreciated attribute in all clusters. The most liked and most often chosen cultivar, 'Aroma' is crispy and fairly sour, which are typical characteristics of domestic cultivars. It was widely appreciated across the respondent spectrum and well liked even in the 'sweet' cluster (CL1).

Respondents obviously preferred crispiness because they regarded it as a sign of freshness and proper maturity stage (Mäkinen & Malkki 2004; Péneau et al. 2007). Surprisingly though, sweet and somewhat mealy 'Pekka' got high mean scores in the third session from the CL3(sweet & sour). Maybe the respondents in CL3 were more willing to experiment, although the reason for this was not revealed. Firm apples were most appreciated in 'sour' cluster (CL3), in line with the literature (Carbonell et al. 2008; Egger et al. 2010; Tomala et al. 2009). Similarly, the two other clusters, CL1(sweet) and CL2(sweet & sour) resembled the clusters in the literature.

Although sweetness was rated higher than sourness in the ideal apple questionnaire, hedonic ratings and clustering results showed that sour and medium sour apples were liked by many respondents. Interestingly, many respondents in CL1(sweet) preferred sour and crispy 'Aroma' over sweet 'Pekka', and they chose even more 'Aroma' in the second session than in the first, although the mean liking dropped by 0.5 units. The reason for this could be, in accordance with Alavoine et al. (1990) that Finns as a Northern people are used to quite sour

and even hard apples, as most traditional varieties are low in sweetness. In addition, these apples are often eaten slightly unripe, especially if picked from home gardens. Thus, liking sweet apples means a completely different concept in Finland than for example in South Europe.

Logistic regression models explaining apple choices changed substantially between sessions (III). Initial liking was not a very good predictor in subsequent sessions, although in some cases, success rates remained good. The main predictors of choice between cultivars were the hedonic ratings of the participants and to a smaller extent their HedFlex and general orientations towards apples. Liking of the cultivar chosen was included in almost all of the models. More interestingly, one or more ratings of liking of other cultivars entered as a negative term. Thus, typical strategy in choosing a food item is to screen out the unacceptable options and then make the final decision of acceptance among the remaining alternatives (Mustonen et al. 2007).

Liking of 'Red Atlas' entered into the majority of the models as a negative term. As 'Red Atlas' is a cultivar with high sourness, many participants may have reacted with rejection. However, there were also individuals who liked such apples and their number increased along the sessions, although the overall proportion of this cultivar in the choices was small. Hence, different products will be needed for different consumer segments to satisfy individual preferences (Alavoine et al. 1990; Carbonell et al. 2008; Harker et al. 2003). CSI, Change Seeker Index (Steenkamp & Baumgartner 1995) did not predict the choice of apples, nor did it predict the HedFlex score. Similar results were obtained by Mustonen et al. (2007) with cheeses.

Giving the respondents apples for home use after tasting them was based on the assumption that being able to re-taste the samples in home conditions would enhance the ability to elaborate opinions (Mustonen et al. 2007) and drive further evaluations and choices. These circumstances combined characteristics of laboratory testing and real exposure. Ratings based on real exposure are likely to give more reliable results than brief laboratory testing.

6.4 Monetary value of domestic apples

The monetary value of domestic apples and its relationship with perceived pleasantness and other attributes were examined in Study IV. Mean WTP was 2.36 euro/kg, but for the best liked cultivar 'Tobias' it rose to 2.67 in the second round of TR2 and TR3. The respondents who reported consuming domestic apples more often than once a week had from 0.52 to 0.74 euro/kg higher WTP than those who consumed them less frequently. This suggests that the WTP increases when the product is familiar. Respondents tend to like more the products they

frequently use (Kähkönen & Tuorila 1999), but here the difference in monetary value was also clear.

Differences between cultivars in pleasantness and WTP were rather small when the ratings were based on the appearance of the auctioned apple cultivars. Substantial differences emerged, when other aspects were added, especially written information and tasting combined. Currently, in a normal shopping situation, the customers receive very little information about the cultivars available (either domestic or imported). In the future we could apply BDM method in a real shopping situation, where the imported and domestic apples are side by side. The advantage of the BDM method is that it is applicable in the market setting with the label information present, although here random codes were used.

In a grocery shop, the customers are typically able to examine only the extrinsic properties of the fruits such as colour and size, which makes it more difficult for a less frequent shopper to recognise what to choose. Consequently, repeated purchases ultimately depend on whether the inner sensory properties were well-liked. Literature has shown that information has an effect on the hedonic ratings and WTP, and its magnitude and direction depend on the samples tested (Combris et al. 2009; Kähkönen et al. 1996; Lange et al. 2000). The regression models as a function of pleasantness explained about half of the WTP, while the differences between the cultivars were substantial.

Means in the ratings of individual cultivars showed that sour 'Konsta' was regarded as the least pleasant and the least-sour 'Tobias' as the most pleasant, and WTP was in agreement with the hedonic ratings. The effect of tasting after visual inspection was positive in three cultivars and negative in one ('Konsta'). For one cultivar ('Tobias'), information given before tasting created expectations that were not fulfilled. Consequently, tasting decreased the perceived pleasantness of 'Tobias' sharply, contrary to the WTP, which declined more moderately. The reason behind the disappointment to the taste of 'Tobias' and resulting in decrease of pleasantness may be that the consumer quality of 'Tobias' was not as good as was expected. It may have been slightly overripe especially towards the end of the two week experiment. It was slightly mealier and less crispy than what had been expected based on the previous years' GDA. In addition to the clear red skin, 'Tobias' has red stripes or larger areas of red in the flesh and thus may have increased in WTP in spite of the disappointment caused by tasting.

Information after tasting did not affect the hedonic ratings or WTP in any of the cultivars. Thus, tasting is of utmost importance in experiencing the product and making choices (Arvola et al. 1999). The case with 'Tobias' showed that great care must be taken when writing written descriptions to make them valid and understandable to all user groups. Information of the character of 'Konsta' had a clear meaning to Finns: when an apple is a process apple, it is sour, crispy and firm. However, as 'Konsta' was only medium crispy, it proved to be a disappointment and pleasantness declined. However, while liking of 'Konsta'

decreased because of the information concerning its nature, the result was no doubt more realistic than when estimation was based on the appearance only, and consequently caused less disappointments.

While both methods revealed fairly similar discrimination between the cultivars, there were also differences. The pleasantness ratings differentiated the cultivars slightly better, but WTP procedure revealed the effect of use frequency on the monetary value of the apples. The result suggests that the frequent eaters of a food product are more willing to pay higher price for it because they are familiar with it. This is supported with the findings from the comments analysis by Galmarini et al. (2013): the respondents who ate apples daily mentioned more descriptive words and cultivar names than those who ate them less frequently, i.e. the vocabulary concerning apples was more familiar. Similarly, a well-branded (and thus, well-known) product is a valuable asset (Jaeger 2006).

To maximise consumer satisfaction and repurchases it is important to know consumers' preferences and WTP for different products. As for the apple cultivars, new crosses are traditionally selected for cultivation based on few opinions (usually that of the breeders) (Hampson et al. 2000), which does not guarantee that the sensory quality of these apples is agreeable.

It is also important that right products are directed for right purposes and that individual preferences are appreciated. The results of Study IV emphasise how important it is that the consumers have a chance to taste the product before their purchase decision, and that the cultivars are labelled so that the consumers are able to re-purchase their favourite cultivar. This could encourage farmers to use alternative forms of market channels such as farmer's market or the other forms of farmer-to-consumer direct marketing.

Clear labelling and attractive but honest information about the characteristics of the apples may also encourage those consumers who do not eat apples often to try them. In this way even the food-related boredom (Mela 2001) may be overcome. Appropriate labelling of domestic cultivars should not be impossible, as it is already done with potatoes. Some markets even have folders presenting information about the exotic fruits and vegetables that the customers can review, so why not about domestic produce?

6.5 How consumers see domestic apples

Vocabulary of the words and expressions that Finnish apple consumers relate to their most favourite apple were collected to gain insight of the perceptions of apple users. Currently domestic apples are poorly differentiated or branded in the retail stores. Sometime not even the name of the cultivar is shown. This is apparently not a completely unknown phenomenon.

Galmarini et al. (2013) noted that in Argentina, often only the price and the cultivar name are given in a grocery store, while in France, apples are always accompanied with descriptions of the cultivar characteristics. In addition, the Finnish fruit market is challenging, as imported apples of good quality are often sold at a very low price (1-2 euro/kg). Imported apples are a popular special offer product in the super markets. The price range for domestic apples is large (depending on the cultivar, quality class, place and time of the season), but typically they cost three to five euro/kg.

Milà i Canals et al. (2007) showed that during autumn and early winter within EU, energy use per kg domestic (local) apples was half of the energy input required to produce and transport the equivalent amount of apples from Southern Hemisphere to the retail stores. Apples were also considerably more economical when produced and transported from another EU-country throughout the year. Although the key figures used in estimating the EU-production and transport do not entirely correspond to the situation in Finland, which is quite far away from the rest of Europe and where the average yield is modest, the research shows that vast importation is not always the best solution.

In the vocabulary collected, there were surprisingly few mentions of the origin of the apples. The reason for this is that the respondents knew that the question was about domestic apples so they did not have to report preferred origin. However, the importance of the origin was revealed through many other expressions, such as "apples can be eaten unpeeled", "apples can be eaten unwashed", and "I can eat the whole apple except the wooden core", and also during unofficial discussions with the respondents during recruitment. These and the expressions like "clean" and "free of toxic chemicals" show that the respondents related domestic apples to naturalness as well as to healthiness. Using laddering technique (e.g. Roininen et al. 2006) or interviewing would have given more insight on this topic. Unfortunately the time frame prevented that.

The vocabulary contained more texture than flavour related expressions, while in Andani et al. (2001) and Swahn et al. (2010) their numbers were quite equal. The ideal apple descriptions contained also a substantial amount of textural flavour expressions ("mealy taste", "juicy taste") as well as hedonic, flavour related expressions ("good taste", "tasty"). The number of flavour attributes compared to the appearance descriptors suggests that flavour has more relevance to Finns than specific appearance, similarly to French (Galmarini et al. 2013).

Breeding programs tend to stress red colour (Bonany et al. 2013; Iglesias et al. 2008). During this study, the retail sector in Finland has indicated that they too favour red apples, and preferably big ones. However, inspecting the consumer vocabulary, the picture is quite the opposite. Specific colour was mentioned 34 times, and only 20 among 122 respondents wanted red apples. In addition, several of them indicated liking bi-coloured apples as well. Very few had exact demands on the size of the apples, and some even mentioned liking

medium or small sized apples. These findings were in accordance with Mäkinen & Malkki (2004).

Thus, stressing the colour is a double-edged sword. While it may draw attention to the fruit, in reality it may lead to a disappointment, if the eating quality does not correspond to the expectations the colour has created. Pleasant texture and flavour are more important reasons than colour itself for acceptance and returning to the fruit again (Daillant-Spinnler et al. 1996; Harker et al. 2003; Jesionkowska et al. 2006; Kühn & Thybo 2001a). In addition, some consumers do prefer other than red apples (Jaeger & MacFie 2001, Kühne & Thybo 2001).

6.6 Methodological considerations

When Study I was initiated in the summer of 2009, there was almost nothing: no descriptors, no methods, nor a panel, and not even any precise information about the sensory variety among the domestic cultivars (other than the general understanding that it is huge), and the apples to be evaluated hung unripe on the trees. Studying horticultural literature such as Meurman & Collan (1943), Krannila & Paalo (2008) and Tahvonen (2007) familiarised the research team with the typical characteristics of domestic cultivars, although this literature did not contain any proper sensory data. In the summer and early autumn it was not possible to know if the lexicon generated would be valid also for the late season cultivars, as they were not available during the construction of the lexicon. However, the lexicon turned out to be quite accurate, as only minor improvements were needed to the descriptors before Study II (the second year).

Very early it was decided that following the principles of the GDA presented by Lawless & Heymann (2010) were the best starting point as they are quite practical. Thorough study of the pioneering literature, such as Williams & Carter (1977), Watada et al. (1980), Daillant-Spinnler (1996), Jaeger et al. (1998), and the abundant publications by Harker and his colleagues (e.g. Harker et al. 2002b; 2002c) gave understanding of the basic sensory characteristics of the apples. The red light used during the odour, texture and flavour evaluation was adopted from Karlsen et al. (1999).

At the beginning of the first harvest year, panellists generated the lexicon and agreed on the references with the panel leaders, which Lawless & Heymann (2010) call "consensus training", while the next two times, training was a combination of "consensus training" and "ballot training", where the lexicon is given by the panel leader. As some of the assessors had participated in the panel the previous year(s), there was also continuity in the panel work. An optimal situation would have been to have the same assessors throughout the study, but this was not possible because some volunteers graduated, while others moved away or changed positions.

After thorough consideration the consensus was reached that the apples will be evaluated whole and unpeeled. As it is a common habit to eat domestic apples uncut and unpeeled in Finland peeling would have caused unnatural conditions. Using unpeeled apples is not unusual, although not the most common way to present apples in descriptive analysis. Several different presentation modes have been used in the literature. Watada et al. (1980) used unpeeled pieces for textural and peeled pieces for odour and flavour attributes. Karlsen et al. (1999) had unpeeled apple halves, while Kühn & Thybo (2001a) and Thybo et al. (2003) presented unpeeled apple quarters. Dever et al. (1995) showed that different sides (blush/non-blush, top/bottom) of a single apple had different sensory properties. In addition, some domestic cultivars start to brown in less than five minutes. As evaluation itself often took much longer than that, browning of the samples would have been difficult to handle properly. Williams & Carter (1977) concluded that serving apple slices instead of the whole apples during descriptive analysis gave no advantage in the evaluation; it only made the procedure more laborious.

As the studies were done in Finnish, correct translations were not a severe question during the evaluations. Translation may cause challenges in the international research community or if the panel is multilingual. For example, the concept "mealy" could also be translated as "floury", "mushy" or even "pulpy". The word "mealy" was chosen to be used in translations, in accordance with e.g. Watada et al. (1980), Kühn & Thybo (2001b) and Thybo et al. (2005). Karlsen et al. (1999) used the word "mushiness" and Swahn et al. (2010) "graininess", depicting the amount of granules felt in the mouth. The word "mealy" was used in this study to refer to a soft, dry and sometimes even grainy texture, described by Andani et al. (2001). The Finnish word "jauhoinen" in the context of apples has a very clear meaning to every Finn. The traditional cultivars 'Cinnamon apple' and 'Transparente Blanche' are famous for becoming mealy when overripe.

The cultivar selection was wide and contained both dessert and process type apples. Some of the cultivars were known or anticipated (as most of them had not been studied before with sensory methods) to be modest in their sensory quality. The purpose was to gain a broad perspective of the sensory spectrum of domestic cultivars. The poor storability of the early and some mid-season cultivars made the evaluation challenging, as the earliest apples were not available anymore when the last cultivars reached commercial maturity. This non-continuity in the availability of the samples may have caused fluctuation in the intensities evaluated. Thus, the attribute intensities are more relative than exact in nature.

Both the sensory and consumer panels were predominantly female. In Study III, 28% of the respondents were male, while in Study IV, the proportion of males was 19%. In a properly trained descriptive panel, gender should not have any relevance, while in consumer studies, balance could have been better. Unfortunately, a larger proportion of males was not possible to recruit in the timeframe. In most Finnish universities and research institutes (other than in

the field of engineering) the majority of the personnel and students are female. The situation is quite similar in many offices, too.

The respondents were volunteers from the greater Helsinki area who were able and willing to participate in the studies. In addition, our requirement to visit the test site three times in Study III reduced the availability of the participants. Consequently, the respondents in the consumer studies were a convenience sample, and accordingly, care needs be taken when applying the results to the whole population. However, the main point, recruiting urban apple eaters was reached. Statistical analysis did not reveal any major differences between genders in either of the consumer studies.

7 CONCLUSIONS

A procedure for the sensory characterisation of a wide selection of Finnish apple cultivars was established for the first time. The descriptors aimed at finding the focal attributes to be used when the characteristic features of the cultivars are communicated both to the apple professionals and to a wider audience. This will facilitate finding the right kind of apples for different purposes and preferences. The apples were categorised into four clusters according to the way their sensory profiles changed at different stages of storage. Most of the storage induced changes in the cultivars were minor during the normal commercial period. However, cultivars shifting between clusters during storage suggest that marketing should take the phase of apple cultivar into consideration, as apples at various phases may attract different consumer segments.

The results of the consumer studies showed that an apple is chosen on the basis of both liking the chosen cultivar and disliking the non-chosen cultivars. It can be speculated that this could apply also to a wider selection of other food. The main predictors of choice were the hedonic ratings of the participants or their orientation towards apples. Moreover, initial liking was not very good at explaining later liking. In a shopping situation, when the products are offered side by side, also the properties of the less preferred options have an effect on the process of choice. The differences between the cultivars in the ratings of pleasantness and WTP were rather small when the decision was made based only on the appearance, which is the most typical situation in the shops. Written information and especially tasting revealed differences between the cultivars, demonstrating how vital it is that the consumers have a chance to taste the product before their purchase decision, and that the cultivars are labelled so that they can easily be recognised by the shoppers.

The ideal apple vocabulary showed that Finnish apple consumers do not just have a single preferred domestic apple, but obviously a versatile selection of cultivars is best for the optimum variety to satisfy individual preferences. Relevant information in the written descriptions by the apples in the shops would make the apples more accessible also to the less frequent users, who are not familiar with the typical expressions in the horticultural literature. Especially expressions having hedonic aspect (such as "agreeable", "pleasant") should be avoided, because the consumers differ greatly in their preferences. For example, "agreeable tartness" means a totally different thing to a consumer who likes sour apples and to another who loves sweet apples.

The demand and supply of domestic apples does not always meet, resulting in disappointment among the prospective customers as well as in the retail shops. Effective promoting of domestic apple cultivation and branding accompanied with an enhanced supply-chain would help in increasing apple consumption, and might enhance also the

consumption of fruits and vegetables in general, which would all benefit both the public health and agriculture, and especially local and rural economy. It is worthwhile to look beyond the most apparent features of the domestic apples (i.e. size, shape and colour) and appreciate also the intangible features, such as "clean", "safe", "local" and natural, which were clearly observed in this study.

It seems that the frequent eaters of a food product are more willing to pay a higher price for their purchase because they know what they are paying for. This suggests that the promotion of domestic apple consumption eventually also promotes the prices paid for them. As the more frequent apple eaters were willing to pay over 0.5 euro/kg more for the domestic apples than the less frequent eaters, the best strategy in promoting domestic apple consumption would be twofold. Enhancing the availability of good-quality apples would satisfy the needs of the frequent eaters. Increasing education about the qualities and characters of the apples among the less frequent eaters would increase their knowledge and might make them more eager to try new cultivars. In both cases branding and clear labelling would increase not only consumption but appreciation as well.

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