Relating physico-chemical properties of frozen green peas (*Pisum sativum L.*) with sensory quality

Sensory and physico-chemical properties of frozen green peas

Kathleen M. Nleya, Amanda Minnaar and Henriëtte L. de Kock*

Dept of Food Science, University of Pretoria, Private Bag X20, Hatfield, 0028, South Africa

*Corresponding author: Henriëtte L. de Kock riette.dekock@up.ac.za

Abstract

BACKGROUND: The acceptability of frozen green peas depends on their sensory quality. There is a need to relate physico-chemical parameters to sensory quality. In this research, six brands of frozen green peas representing product sold for retail and caterer's markets were purchased and subjected to descriptive sensory evaluation and physico-chemical analyses (including dry matter content, alcohol insoluble solids content, starch content, °Brix, residual peroxidase activity, size sorting, hardness using texture analysis and colour measurements) to assess and explain product quality.

RESULTS: The sensory quality of frozen green peas, particularly texture properties, were well explained using physico-chemical methods of analysis notably alcohol insoluble solids, starch content, hardness and °Brix. Generally, retail class peas were of superior sensory quality to caterer's class peas although one caterer's brand was comparable to the retail brands. Retail class peas were sweeter, smaller, greener, more moist and more tender than the caterer's peas. Retail class peas also had higher °Brix, a*, hue and chroma values; lower starch, alcohol insoluble solids, dry matter content and hardness measured.

CONCLUSIONS: The sensory quality of frozen green peas can be partially predicted by measuring physico-chemical parameters particularly °Brix and to a lesser extent hardness by texture analyser, alcohol insoluble solids, dry matter and starch content.

Keywords: Peas**;** Sensory quality; retail grade; caterer's grade

INTRODUCTION

Peas (*Pisum sativum* L.) are one of the four important legumes cultivated worldwide; soyabeans, groundnuts and beans make up the rest.[1] The use of green garden peas as a vegetable crop is attributed to their relatively simple production, pleasant taste and high nutritional value.[2] The popularity of fresh garden peas has decreased markedly in developed countries primarily due to harvest and distribution expenses and the availability of convenient frozen peas throughout the year.[3] Shortly after harvest, loss of sensory characteristics such as sweetness, crispness as well as degreening and the development of mealiness may reduce green pea quality.[4] Alcohol insoluble solids (AIS) have been used as a maturity index for fresh green peas[5] as this parameter relates to protein, dietary fibre and starch content. As peas mature, sugars convert to starch and larger peas consistently exhibit higher AIS and dry matter content. [6, 3] These parameters are negatively correlated with the sensory quality of the harvested peas. Processing steps such as blanching, if not conducted efficiently, may lead to colour changes in the pea seeds by pheophytisation reactions.[7] Colour and flavour changes might also be due to residual enzymatic activity[8] and temperature abuse during storage.[9]

Quality grading is done during processing in accordance to the Agricultural Product Standard Act of South Africa[10]. Frozen peas for retail brands are selected from pea batches graded as *Choice* with no or only a few deviations in appearance, flavour and texture attributes while peas for caterer's brands are classed as *Standard* grade implying a larger number of quality deviations. Sensory evaluation as a quality control tool in industry has limitations e.g. it is time consuming and tedious, make use of assessors with varying sensory sensitivities which may lead to inconsistencies and/or subjective judgements. A better understanding of sensory characteristics of frozen green peas in relation to their physico-chemical properties may provide valuable quality control tools. The objective of this study was to determine the descriptive sensory profiles of different commercial brands of frozen green peas and relate them to associated physico-chemical measurements of colour, seed size, hardness, residual enzyme activity, °Brix, starch, alcohol insoluble solids and dry matter contents.

MATERIALS AND METHODS

Samples

Representative samples of six different brands of frozen green peas were purchased in wholesale and retail shops in South Africa. The pea brands included three types (RA, RB, and RC) distributed for retail sale, and three types (CA, CB and CC) distributed for catering sale. Four batches with different production dates were purchased per brand. Ten kilograms of each batch were pooled, mixed and stored at -18 °C.

Descriptive sensory panellist selection, training and evaluation

Descriptive sensory evaluation was carried out in the University of Pretoria sensory evaluation laboratory. A panel of twelve (10 female and 2 male) non-smoking, self-confessed healthy individuals were screened and selected based on performance in basic taste recognition tests, texture ranking and odour identification tests. Panellists were trained over eleven sessions (1.5

to 2 h each). The generic descriptive analysis method[11] was used in the training of the panel and performance monitoring[12] was done using PanelCheck software version 1.3.2 (www.panelcheck.com, Nofima Norway) to test reproducibility and consistency of the sensory panel ratings and hence improve calibration. Twenty seven descriptors (Table 1) were developed for appearance, flavour and texture attributes of frozen green peas. These were evaluated on a ten-point structured line scale with marked end point anchors (0 and 10). Data was captured using Compusense® *five* (Compusense® *five,* release 4.6, Compusense Inc., Guelph, ON, Canada).

Individual pea portions (± 30 g) were cooked for 5 min over steam in covered stainless steel Bain Marie (Anvil Model BMA 0002, South Africa) compartments with 5 ml of boiling water added to each dish, and served immediately. Pea samples were served at 70 °C in random coded 125 ml styrofoam cups with plastic lids. The panellists were provided with a plastic spoon for eating the peas. Peeled, sliced fresh raw carrots and filtered water was provided for neutralising and cleansing the palate before and between sample tasting.

The trained panellists evaluated the 24 batches of frozen peas in duplicate over six evaluation sessions. This allowed for the evaluation of eight randomly presented samples per session. Pea samples were served monadically every 7 min allowing panellists approximately 5 min to evaluate a sample and a 2 min break between samples. A forced 10 min break was factored in between evaluation of the first four and the last four samples to avoid fatigue. The evaluation was performed by panellists seated at individual evaluation booths under day light illumination.

Colour measurements

Peas (100 g) were thawed at room temperature (±22 °C) for 3 h and packed tightly into a petri dish. L*, a* and b* values were measured at three points on the petri dish using a Chroma Meter CR-400 (Konica Minolta Sensing, Osaka, Japan) with the lens directly touching the peas. Two petri dishes were prepared per batch and 3 readings obtained from each. Prior to the analysis the instrument was calibrated with a standard white tile supplied by the manufacturer. The chroma [$C = (a^{*2} + b^{*2})^{1/2}$] and hue angle ($H° = \arctan b^*/a^*$) were also calculated.

Table 1. Lexicon for descriptive sensory evaluation of steam cooked frozen green peas

Descriptor	Definition	Rating scale (references indicated where applicable)
Visual Appearance		
Green colour intensity	Level of greenness of outer surface of peas	0=not green 10=extremely green[a]
Green colour uniformity	Estimated level of homogeneity in colour of pea seeds	0=not uniform 10=extremely uniform
Seed size	Physical dimensions of pea seeds	0=not large 10=extremely large[a]
Seed size uniformity	Estimated level of homogeneity in size of pea seeds	0=not uniform 10=extremely uniform
Exterior seed surface texture	Degree of shrivelling of outer skin surface	0=not wrinkled (fresh prune) 10=extremely wrinkled (dried prune)
Seed shape	Characteristic surface outline/fullness of pea seeds	0=not round 10=extremely round[a]
Overall seed shape uniformity	Estimated level of homogeneity in shape of pea seeds	0=not uniform 10=extremely uniform
Flavour		
Aroma intensity	The strength of odour that is released from the peas upon taking the first few sniffs	0=not intense 10=extremely intense
Sweet aroma	Aromatic associated with high sugar content vegetables	0=not sweet (filtered water) 10=extremely sweet (freshly boiled sweet corn)
Earthy aroma	Aromatic characteristic of damp soil, wet foliage or undercooked potato	0=not intense 10=extremely intense (unpeeled and cut raw-undercooked potato)
Acetone aroma	Aromatic characteristic of ketones, specifically acetone	0=not intense 10=extremely intense (acetone)
Beany aroma	Aromatic characteristic of leguminous seeds	0=not intense 10=extremely intense (boiled sugar beans)
Green aroma	Aromatic associated with freshly cut green vegetables	0=not intense 10=extremely intense (freshly cut green beans)
Sweet taste	Taste on tongue stimulated by sugars and high potency sweeteners	0=not sweet 10=extremely sweet (50% sucrose solution on filter paper)
Bitter taste	Taste on tongue stimulated by caffeine, quinine and certain other alkaloids	0=not bitter 10=extremely bitter (4% caffeine solution on filter paper)
Starchy flavour	Flavour associated with tubers particularly boiled potato	0=not intense 10=extremely intense (boiled potato)
Fresh flavour	Flavour associated with fresh green peas, free from any unfavourable/stale odours	0=not fresh (boiled peas kept at 22 °C for 5 days), 10=extremely fresh (fresh green peas steam cooked for 5 min)

Table 1. Lexicon for descriptive sensory evaluation of steam cooked frozen green peas

Descriptor	Definition	Rating scale (references indicated where applicable)
Fruity flavour	Flavour associated with fully ripened fruit characteristic of aldehydes and ketones	0=not intense 10=extremely intense (overripe pear)
Flavour intensity	Strength of flavour concentration released in mouth when pea sample is chewed	0=not intense 10=extremely intense
Bitter aftertaste	Intensity of bitter taste that lingers after swallowing	0=not bitter 10=extremely bitter
Texture		
Crunchiness	Pitch of sound produced when chewing peas	0=not crunchy 10=extremely crunchy (raw carrots)
Tenderness	Ease with which peas are masticated in the mouth	0=not tender 10=extremely tender (overcooked sugar beans)
Mealiness	Extent of granularity in texture experienced when chewing peas	0=not mealy 10=extremely mealy (80% moisture content maize meal paste)
Chewiness	Amount of work required to masticate a pea sample with molars	0=not chewy 10=extremely chewy[a]
Moistness	The amount of juice released from peas upon chewing a spoon full of peas	0=not moist 10=extremely moist[a]
Uniformity in texture	Estimated level of homogeneity in texture in a spoonful of peas	0=not uniform 10=extremely uniform
Residue remaining after swallowing	The amount of pea pieces that remain in mouth after chewing and swallowing	0=no residue 10=plenty of residue (roasted peanuts)

[a]Selected pea samples used as references and did not necessarily represent the extreme level for the particular descriptor

Size sorting

For each frozen pea batch 500 g was sieved through different square stainless steel plates (200 x 200 x 2 mm) with holes gradually decreasing in diameter size from 14 to 6 mm. For each batch, enough seeds to cover the base of the plate were gently manually shaken for 30 s through the plates. The seeds that did not pass through the sieve were placed in ziplock bags and those that did were passed through the subsequent lower diameter sieve plate. This was done repeatedly until all seeds in the 500 g were passed through the sieves. The pea seeds collected at the different sieve sizes were weighed and the percentages calculated. The experiment was conducted three times per batch.

°Brix (Soluble solids) content

Frozen peas (50 g) packed into 100 ml round bottom plastic containers were covered with cheese cloth secured by rubber bands and dehyrated for 8 days in a freeze drier (Instruvac lyophilizer model 13KL, Vacuum and temperature settings: -85 kPa and -40 °C). The dried seeds were ground into a powder of particle size not more than 0.5 mm using a IKA® A11 basic analytical mill (230 V, 50/60 Hz). The freeze dried pea flour (1 g) was reconstituted with 4 g distilled water in a glass beaker to an 80 % moisture content paste. This reconstitution ratio was selected to imitate the typical moisture content of about 80 %, calculated from dry matter content of commercially frozen peas of 20.5 %.[13] The paste was incubated in a 20 °C water bath for 5 min, squeezed through cheese cloth and the soluble solids content (°Brix) of the liquid measured using a Pal-1 digital pocket refractometer (Brix 0-53°, Atago, USA). The analysis was carried out three times for each batch.

Dry matter content (DMC)

DMC of thawed uncooked peas was determined by drying 5 g of peas to a constant weight (±20 h) in a draught oven at 70 °C.[14] The experiment was carried out three times for each batch.

Peroxidase activity test

Frozen peas (50 g) were thawed at room temperature (23 °C) for 2 h. Ten randomly selected pea seeds were longitudinally cut and arranged with the cotyledon surface exposed and sprayed with peroxidase test solution (50:50 1% guaiacol and 2% hydrogen peroxide). Inadequately blanched batches were recorded as those showing colour change in more than one of the seeds within 10 s of spraying the solution[10]. The analysis was carried out three times for each batch.

Alcohol insoluble solids (AIS)

The AIS content of thawed peas was measured using the gravimetric method.[15] A blend of 1:1 w/w of 20 g peas and distilled water was analysed in triplicate for each batch.

Starch content

Starch content was measured on freeze dried pea flour (prepared as described for sugar analysis) using the Megazyme alpha-amylase/amyloglucosidase test kit (Megazyme International, Ireland) based on the AOAC Method 996.11; AACC Method 76.13 and ICC Standard Method No. 168. The analysis was performed in duplicate.

Texture measurements

Peas were cooked using the method prescribed for descriptive sensory evaluation and cooled for 30 min in closed styrofoam cups. A TA-XT2 texture analyser (Stable Micro Systems, Godalming, UK) fitted with a multiple pea rig probe was used to measure the force of compression to pierce through peas. The probe comprises of a round based metal plate with 18 individual circular grooves in which individual pea seeds can be placed and a top plate fitted with 18 metal spikes (1 mm) that fit through the holes on the base plate. Eighteen cooked seeds were randomly selected, weighed and arranged in the probe base plate. The area under the curve (AUC) measured between time 0 and the second highest peak (final penetration) multiplied by the test speed of 10 mm s^{-1} for every gram of sample was used to report pea hardness (work done). The mass of peas was factored into the texture calculation because single pea seeds measured were selected randomly and were visibly of different sizes. The texture analyser used pre-test, test and post-test speeds set at 10.0 mm s^{-1}; a rupture test speed of 4 mm s^{-1}, distance of 15 mm, load cell at 25 kg, temperature at 25 °C, force set at 0.98 N and time set at 5 s. The analysis was performed six times on every batch.

Statistical analyses

A hierarchically nested design analysis of variance (ANOVA) of the General Linear Model (GLM) in Statistica version 7 (Statsoft, Inc., 2006) was used to analyse variance amongst pea brands for physic-chemical and sensory data. The design had three factor levels (batches, brands and classes) in which the batches were considered random effects, and brands and classes were fixed effects. Four batches were nested within six brands which were nested between two classes of retail and caterer's peas (2 x 3 x 4 nested design). The Fisher Least Significance Difference (LSD) test at 5% level of significance was used to investigate the nature of the differences and the least square means obtained were reported for this evaluation. Partial Least Squares (PLS) Regression measured by The Unscrambler version x10.0 data analytical software (Camo software Inc, Oslo, Norway 2009-2010) was used to investigate the relationship of sensory and physico-chemical data for the flavour and texture attributes. An X-Y matrix with physico-chemical attributes as the X variables and sensory attributes as Y variables with full cross validation was computed.

RESULTS

Significant differences were observed between the retail and caterer's peas for all the visual sensory attributes except uniformity in seed shape (Table 2). At brand level differences in ratings for uniformity (of colour, seed size and seed shape) for the different brands were smaller than for the other descriptors, but still indicated statistical differences ($p < 0.05$). Retail brand RA did not differ significantly from catering brand CA in green colour intensity and uniformity, uniformity in shape and size and the exterior seed surface texture (i.e. presence of wrinkles on skin surface). Brand CB with the lowest green colour intensity had the largest and roundest peas.

Significant differences were observed between retail and catering peas for all measured colour parameters (Table 3) except L^*. At brand level however, significant differences were observed for L^* values. Brand CB with the lowest b^* value was significantly different from all other brands. Interestingly, retail brand RA and catering brand CA did not differ for all colour measurements (L^*, a^*, b^*, C and °H).

The six brands of peas displayed different size profiles. Figure 1 shows the size variation for three brands. Brand RA had two distinct size patterns with batches RA1 and RA4 having their largest fraction of peas falling between the size range 8 to 9 mm while RA2 and RA3 had their largest fractions between 9 and 10 mm. Batches in brand CA showed the most uniformity with most seeds between 9 and 10 mm. Brand CC peas varied greatly in size.

Table 2. Means (± standard deviations) of visual appearance attributes for (a) the different classes and (b) brands of frozen green peas as evaluated by a descriptive sensory panel

	Green colour	Uniformity in colour	Seed size	Seed size uniformity	Exterior seed surface texture	Seed shape	Uniformity in seed shape
(a) Retail	5.8^{a}(±0.8)	5.7^{a} (±0.5)	5.3^{a}(±1.3)	5.1^{a} (±1.0)	2.9^{a} (±1.1)	5.2^{a} (±0.8)	5.0^{a} (±0.7)
Caterer's	4.9^{b}(±1.6)	4.9^{b} (±1.0)	5.5^{b} (±0.6)	5.4^{b} (±0.8)	3.7^{b} (±1.1)	5.3^{b} (±0.7)	5.1^{a} (±0.7)
(b) RA	6.2^{d} (±0.6)	5.7^{c} (±0.6)	3.9^{a} (±1.2)	6.1^{d} (±0.4)	3.7^{d} (±1.2)	4.9^{b} (±0.6)	5.1^{b} (±0.4)
RB	5.4^{b} (±1.3)	5.8^{c} (±0.5)	6.1^{d} (±0.5)	5.2^{b} (±0.5)	2.0^{a} (±0.5)	5.9^{d} (±0.5)	5.6^{c} (±0.6)
RC	5.8^{c} (±0.3)	5.7^{c} (±0.5)	5.8^{c} (±0.8)	4.2^{a} (±0.9)	3.0^{c} (±0.7)	4.8^{ab} (±0.7)	4.4^{a} (±0.7)
CA	6.1^{d} (±0.6)	5.9^{c} (±0.6)	5.3^{b} (±0.3)	6.2^{d} (±0.4)	3.7^{d} (±0.4)	5.5^{c} (±0.2)	5.4^{bc} (±0.4)
CB	2.9^{a} (±1.0)	4.1^{a} (±0.9)	6.2^{d} (±0.4)	5.6^{c} (±0.2)	2.4^{b} (±0.5)	6.0^{d} (±0.4)	5.5^{bc} (±0.3)
CC	5.7^{c} (±0.3)	4.6^{b} (±0.6)	5.1^{b} (±0.3)	4.4^{a} (±0.3)	5.0^{e} (±0.3)	4.5^{a} (±0.3)	4.4^{a} (±0.5)

[a,b,c,d,e]When comparing classes or brands, mean values with the same letter superscripts in columns do not differ significantly at $p<0.05$

Descriptors rated on a 10 point scale. Refer to table 1 for definitions of descriptors and scale anchors.

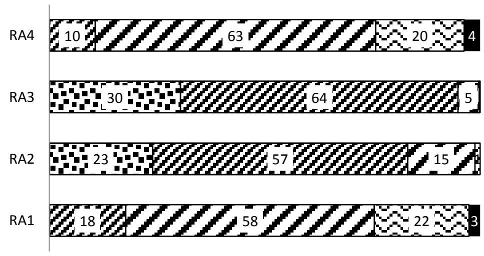
Table 3. Mean (±standard deviations) colour measurement values and calculated °H and C values for (a) the different classes and (b) the brands of thawed green peas

		L*	a*	b*	C	°H
Class	**Retail**	43.3^{a} (±2.3)	-21.2^{a} (±3.1)	25.9^{b} (±3.4)	33.6^{b} (±4.2)	129.3^{b} (±3.8)
	Catering	43.7^{a} (±3.2)	-18.2^{b} (±4.3)	24.1^{a} (±3.4)	30.3^{a} (±4.8)	126.6^{a} (±5.2)
Brand	**RA**	43.4^{ab}(±2.5)	-22.1^{a} (1.7)	25.5^{a} (±2.9.)	33.8^{c} (±2.9)	131.3^{d} (±2.6)
	RB	44.4^{bc}(±1.9)	-20.0^{b} (±4.5)	26.1^{a} (±3.8)	32.9^{bc} (±5.4)	127.1^{b} (±4.4)
	RC	45.1^{cd}(±2.3)	-21.6^{a} (±2.1)	26.2^{a} (±3.7)	34.0^{c} (±3.9)	129.7^{c} (±3.0)
	CA	42.6^{a} (±2.3)	-21.7^{a}(±1.7)	25.2^{a} (±2.9)	33.3^{c} (±2.8)	130.8^{cd} (±3.2)
	CB	46.1^{d} (±3.2)	-13.7^{c} (±3.4)	22.5^{b} (±3.9)	26.3^{a} (±4.9)	121.0^{a} (±3.3)
	CC	42.3^{a} (±2.4)	-19.3^{b} (±2.5)	24.6^{a} (±3.0)	31.3^{b} (±3.6)	128.1^{b} (±2.9)

^{a,b,c,d,e}When comparing classes or brands, mean values with the same letter superscripts in columns do not differ significantly at $p<0.05$

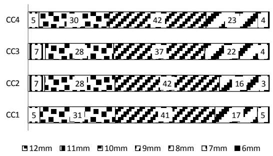
C - Chroma = $(a^{*2} + b^{*2})^{1/2}$)

°H – Hue angle = arctan b*/a*



(a) Retail Brand RA

(b) Caterer's Brand CA



% ratio of peas sieved

(c) Caterer's Brand CC

Figure 1: Size distribution of frozen green peas within three different brands (four batches for each).

Table 4. Partial Least Squares regression used to study relationships between the sensory (Y-block) and physico-chemical (X-block) variables of frozen green peas

		% Cumulative Explained Variances		
		Factor 1	*Factor 2*	*Factor 3*
Y- variables	Aroma intensity	24.5	45.0	46.0
	Sweet aroma	61.1	64.5	64.5
	Earthy aroma	3.0	3.9	4.4
	Acetone aroma	60.3	68.8	75.2
	Green aroma	48.5	61.3	61.4
	Sweet taste	70.7	73.3	73.5
	Bitter taste	62.0	79.6	81.1
	Starchy (boiled potato) flavour	60.7	71.4	71.5
	Fresh taste	73.0	81.4	81.9
	Fruity flavour	20.2	20.3	25.7
	Flavour intensity	9.2	39.9	41.1
	Crunchiness	58.3	72.0	82.4
	Tenderness	81.7	85.3	90.5
	Mealiness	91.9	92.1	92.9
	Chewiness	78.3	78.7	85.0
	Moistness	91.2	91.2	92.6
	Uniformity in texture	0.2	25.4	56.4
	Bitter aftertaste	51.8	81.1	82.5
	Residue remaining in mouth	85.3	85.6	88.3
Explained cumulative variance for Y (sensory) block		**54.3**	**64.3**	**68.3**
X – variables	Starch content	96.2	96.4	96.7
	Alcohol Insoluble Solids content	97.7	98.5	98.9
	Dry Matter Content	1.3	29.2	94.4
	Hardness	89.7	92.9	95.2
	Residual peroxidase positive	1.8	65.7	100.0
	°Brix	78.6	89.1	89.2
Explained cumulative variance for X (Physico-chemical) block		**60.9**	**78.6**	**95.7**

The PLS regression variances for the 19 significant sensory attributes related to flavour and texture (Y variables) and the six physico-chemical attributes (X variables) used to measure them are presented in Table 4. Three PLS factors were significant to report reliable correlations. The sensory texture variables explained the variance in samples more clearly than the flavour attributes. Most texture attributes were explained by the first PLS factor with values between 78.3 and 91.9% except crunchiness with a lower value (58.3%) and overall texture uniformity which was rather negligible as it only explained 0.2%. Mealiness gave the highest explanation of variance in the pea samples. The second and third PLS factors explained more variation in the flavour (taste and aroma attributes). The total variation explained by the X block (physico-chemical measurements) was greater than what was explained by the Y variables (sensory data). DMC and residual peroxidase activity (1.3 and 1.8% respectively) basically did not explain any of the variation in the first factor.

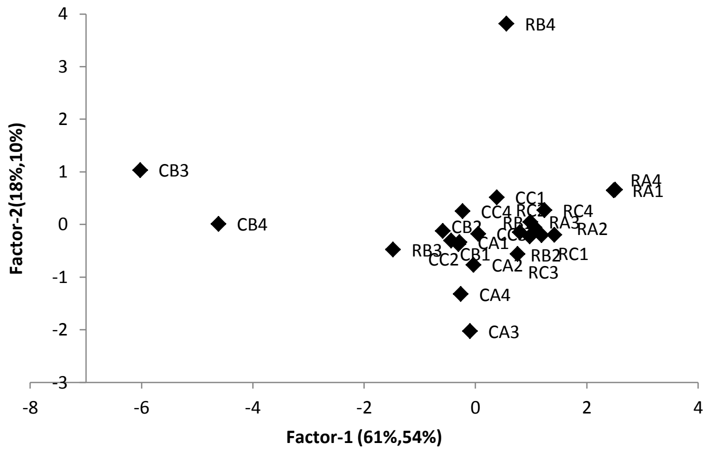
The scores and loading plots (Figure 2) show how the batches and variables are projected along the model components. The retail batches occupy the right side of the plots while the catering batches are found on the left (Fig 2a). A few exceptions include a retail batch RB3 which was situated more to the left amongst other catering samples. RB4 was clearly different from the other samples and positioned at the top of the plot and was thus better explained by the second factor. RB4 was observed to be associated with X-variable high residual peroxidase enzyme activity. The retail samples on the right (particularly batches RA1 and RA4) were associated with high °Brix and those on the left were harder with higher starch and AIS contents. Batches CB3 and CB4 were clearly separated from all the other samples, and were observed to be best explained by the latter three parameters.

PLS prediction models for the flavour and texture X and Y variables identified texture attributes (such as mealiness, chewiness, residue remaining in mouth after swallowing) with the highest explained variances (Table 4) to be useful to make reliable predictions of green pea quality. The texture attributes that gave good prediction models had relatively low Root Mean Square Error of Prediction (RMSEP) and a high correlation coefficient resulting in good linear relationships. Regression coefficients summarize the relationship between all predictors and a given response. The regression coefficients for the flavour and texture sensory variables versus the physico-chemical variables are shown in Table 5. This table show that most of the variability in the sensory attributes was better predicted by soluble solids (°Brix) content as compared to the other physico-chemical parameters. In addition, hardness by texture analyser

Table 5: Partial least squares (PLS) regression coefficients for three factors to summarize the relationship between all predictors (X physico-chemical variables) and Y sensory response variables

	Dry matter content	Alcohol Insoluble Solids	Starch	Hardness	°Brix	Peroxidase positive
Overall aroma	-0.010	0.009	0.003	-0.091	-0.268	0.022
Sweet aroma	-0.012	-0.024	-0.014	-0.038	0.223	-0.028
Earthy aroma	-0.042	-0.006	-0.010	-0.311	-0.477	0.025
Acetone aroma	0.055	0.037	0.027	0.389	0.220	0.023
Green aroma	-0.055	-0.040	-0.028	-0.349	-0.133	-0.019
Sweet taste	-0.002	-0.040	-0.019	0.156	0.701	-0.043
Bitter taste	0.016	0.021	0.013	0.096	-0.093	0.023
Starchy flavour	-0.001	0.018	0.008	-0.195	-0.476	-0.001
Fresh taste	-0.044	-0.054	-0.033	-0.183	0.297	-0.040
Fruity flavour	0.016	0.001	0.003	0.098	0.170	-0.015
Overall flavour	0.014	0.001	0.003	0.181	0.268	0.005
Crunchiness	-0.006	0.025	0.010	0.127	-0.186	0.086
Tenderness	-0.022	-0.046	-0.026	-0.208	0.256	-0.080
Mealiness	0.033	0.048	0.028	0.119	-0.339	0.040
Chewiness	-0.001	0.025	0.011	-0.033	-0.363	0.044
Moistness	-0.032	-0.051	-0.030	-0.138	0.365	-0.054
Uniformity in texture	0.038	0.006	0.010	0.309	0.450	-0.015
Bitter aftertaste	0.009	0.013	0.008	0.056	-0.068	0.017
Remaining residue	0.007	0.029	0.015	-0.013	-0.361	0.037

(a)



(b)

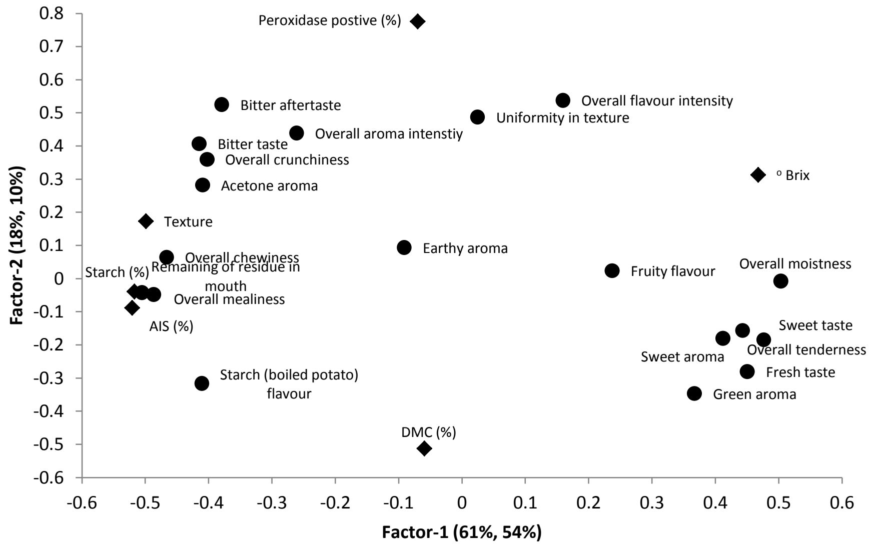


Figure 2: PLS Regression plots of factors 1 and 2 showing frozen pea (a) sample scores and (b) ♦ X (physico-chemical) and ● Y (texture and flavour) loadings

Retail class peas: RA; RB and RC. Caterer's class peas: CA; CB and CC. (Numbers one 1 to 4 indicate different batches)

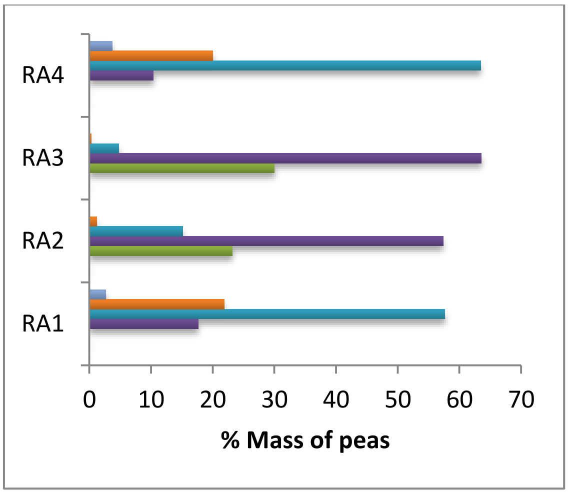
DMC – Dry Matter Content AIS – Alcohol Insoluble Solids predicted acetone and green aroma the best and contributed together with soluble solids content fairly equally to prediction of bitter taste and bitter aftertaste.

DISCUSSION

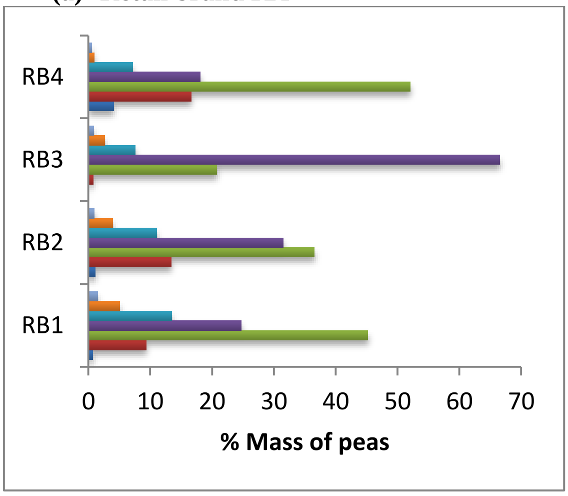
The retail brands showed attributes more favourable for good quality frozen peas. One caterer's brand, CA was comparable to the retail brands. Retail class peas were described as greener than caterer's peas and had significantly more negative a* values (green tone), hue angle and chroma values. The L* scale ranges from 0 for a theoretical black to 100 for a perfect white[16] and a more negative a* value indicates a darker green hue.[17] Batches CB3 and CB4 described to have khaki and dehydrated seeds resulted in brand CB obtaining the highest L* value and the least negative a* value. The khaki colour was probably as a result of loss of chlorophyll from delayed harvest[18] and/or tarnishing of colour from freezer damage.[19] Batch RB4 was olive green and had high overall flavour intensity but low fresh flavour. RB peas with high residual enzyme activity and thus poor colour was probably a result of inadequate blanching.[20] The smaller, greener and higher graded retail peas were, unexpectedly, described to be more wrinkled in appearance than the lower grade caterer's batches. The presence of one or a few depressions on cooked pea skin surface known as dimpling indicate freshness[21] and was possibly described as wrinkling by the panellists. The physical size separation method gave an accurate measure of the size distribution of seeds in each batch and provided a quantifiable measurement for the visual estimate of size uniformity by the panellists. The separation method was therefore more objective than descriptive evaluation. Brands represented by a high ratio of smaller seeds (RA and CA) were described as greener and had lower -a* values and low L* values. Hence size seems to be related to external colour as previously suggested. [14]

Fruity flavour, found to be relevant in describing green pea quality especially when coupled with sweet taste,[22] was significantly lower in brand CC (described to have a weedy flavour) as compared to the other brands. Fruity flavour was negatively correlated to earthy flavour[14] and this relationship was clearly observed in CC.

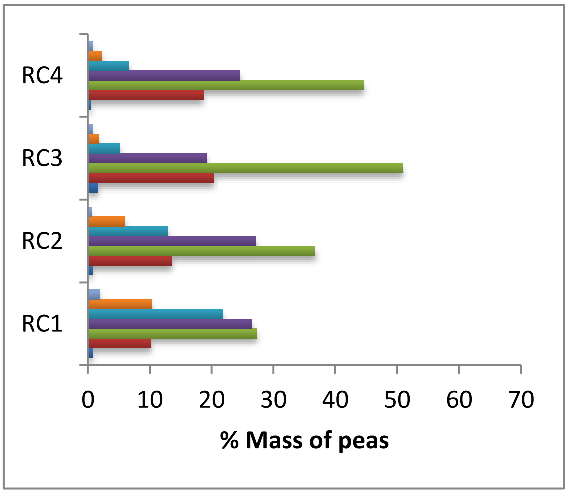
Pyrazines with earthy flavours have been reported in cold peas[22] and could be responsible for the weedy flavour. Acetone aroma detected in batches CB3, CB4 and to a lesser extent in RB4 could possibly be attributed to the presence of ketones and aldehydes formed as products of



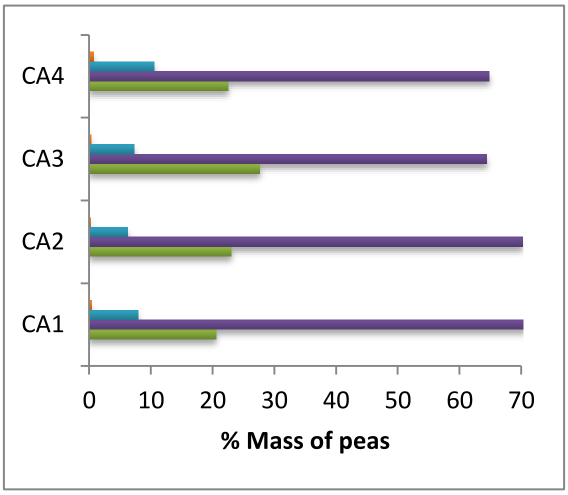
(a) Retail brand RA



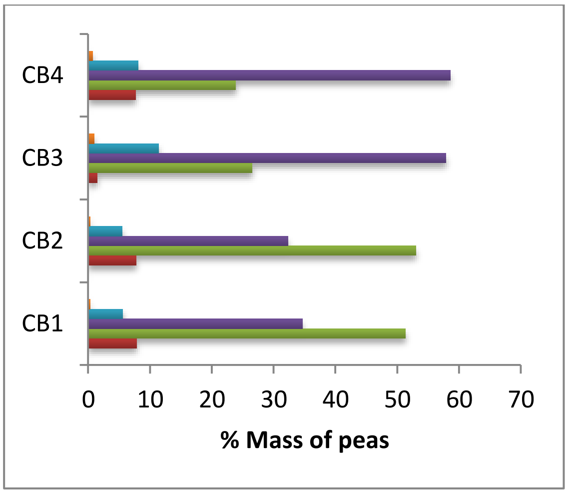
(b) Retail brand RB



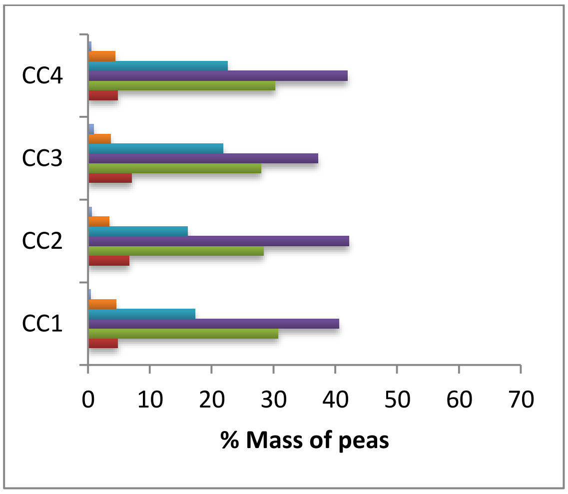
c) Retail brand RC



d) Caterer's brand CA



(e) Caterer's brand CB



(f) Caterer's brand CC

Figure 3: Size distribution of different brands and batches of frozen peas. Graphs (a) to (c) illustrate size fractions obtained for retail brands and graphs (d) to (f) show sizes for caterer's brands

peroxidation reactions[23] by the action of enzymes as addition of lipoxygenase in homogenates of sweet corn showed an increase in painty/acetone odours.[24] The unusual colour of CB3 and CB4 may have overshadowed the flavour perception and influenced panellists to give higher ratings (halo effect) for acetone aroma for these batches since residual peroxidase activity measured in these samples were negative. Objectivity in description of flavour and texture of peas may be enhanced if evaluation of visual properties is separated from evaluation of flavour and texture e.g. with masking of pea colour with red light conditions. However, the influence of visual properties of peas on perception of flavour properties reflects typical quality measurement by consumers when consuming peas.

Sweet smelling and tasting brands had the highest levels of green aroma and fresh taste. A sweetness/sugar content and size relationship was observed with the smaller seeds being sweeter than the large seeds. Underblanched batch RB4 had the third highest °Brix but was not described as sweet by the panel. It is suggested that the action of the enzymes still present in the pea seeds may have increased the soluble solids content of RB4 by breaking down substances such as the fatty acids into more soluble carbonyls thus giving a high soluble solids reading but not necessarily sugar content.[25] Generally, the less sweet peas had more intense boiled potato flavour and were very mealy, and this was verified by physico-chemical analysis as higher starch content. CB3 and CB4 had starch contents of 48 and 45% respectively, typical of mature dry peas.[26] AIS was highly positively correlated to starch content. High DMC, AIS and starch containing batches (CB3 and CB4) had very thick pastes observed when performing the AIS test. This was probably because these batches had very mature dehydrated seeds with high starch content that would result in increased viscosity from swelling of starch granules.[27] AIS, starch and DMC increase with pea maturity.[14] It may thus be concluded that the maturity of peas strongly determines the quality of product. Bitterness described in the less sweet brands (CB) could have been caused by the presence of saponins found in high quantities in peas[28].

Juicier peas are more tender.[29] Samples that were chewy and had high amounts of residue remaining in the mouth after swallowing were less juicy/moist and described to have hard skins, particularly batches CB3 and CB4. The macrosclereid layer with the pectin in the pea testa thickens with maturation causing the pea skins to become tougher and rubbery.[30]

The regression coefficients for sensory and physic-chemical data suggest that sugar content (°Brix) was overall the strongest predictor of sensory quality followed by hardness while AIS, DMC, starch content and the peroxidase test were less reliable for predicting sensory properties of these pea samples. A good representation of pea quality was included in the study and this is important in designing a good, reliable prediction model that can cater for a wide range of samples. Such a model can be used to evaluate for example the characteristics of a new variety of seeds to be introduced in the market or the effects of climatic conditions on quality of produce. Predicted results may be used to implement improvement techniques or make more informed decisions on what to control and regulate to achieve products of good quality.

CONCLUSIONS

The physico-chemical methods used to assess frozen green peas provide sufficient explanations for the sensory profiles and hence quality. The prediction of frozen green pea sensory quality is possible using practical and affordable physico-chemical measurements, particularly measurement of ˚Brix. Size sorting and classification using a simple sieve method was more informative than the visual assessment of size differences by the sensory panel. Hardness measurement by texture analyser, AIS and starch contents are good predictors of pea texture. Blanching is indeed a very critical quality control step in green pea processing. However, underblanched peas are easily identified. It is recommended that the results of this study and that of a consumer acceptability study on the frozen green peas be used to determine consumer defined quality specifications.

ACKNOWLEDGEMENTS

Financial aid from the NRF Technology and Human Resources for Industry (THRIP) Programme TP2010071400011is gratefully acknowledged.

Lukas Danner (Boku University, Vienna) for assisting with research planning and execution.

Marise Kinnear for technical editing of the manuscript.

REFERENCES

1 Ratnayake WS, Hoover R, Shahidi F, Perera C and Jane J, Composition, molecular structure, and physico-chemical properties of starches from four field pea (*Pisum sativum* L.) cultivars. *Food Chem* **74**: 189-202 (2001).

2 Jovicevic D, Gvozdenovic D, Burgarski D, Gvozdanovic-Varga J and Tatic M, New varieties of garden peas (*Pisum sativum* L.) in Yugoslavia, Proceedings of the 2nd Balkan Symposium on vegetables and potatoes. *Acta Hortic* **579**: 181-183 (2002).

3 Deshpande SS and Adsule RN, Garden Pea, in *Handbook in Vegetable Science and Technology: Production, Composition, processing and storage*, ed. by Salunkhe DK and Sadam SS. Marcel and Dekker Inc., New York, USA, pp. 433-456 (1998).

4 Basterrechea M and Hicks JR, Effect of maturity on carbohydrate changes in sugar snap peapods during storage. *Sci Hortic-Amsterdam* **48**: 1-8 (1991).

5 WHO/FAO, Food standards programme codex committee on processed fruits and vegetables: Methods of analysis and sampling of processed fruits and vegetables, 22nd session, Washington DC, USA, 27 Sept-10 Oct (2004).

6 Martínez C, Ros G, Periago MJ, López G, Ortuno, J and Rincón F, Physico-Chemical and Sensory Quality Criteria of Green Beans (*Phaseolus vulgaris*, L.). *Lebensm-Wiss Technol* **28**: 515–520 (1995).

7 Lau MH, Tang J and Swanson BG, Kinetics of textural and color changes in green asparagus during thermal treatments. *J Food Eng* **45**: 231-236 (2000).

8 Henderson HM, Kanhai J and Eskin NAM, The enzymic release of fatty acids from phosphatidylcholine in green peas (*Pisum sativum*), *Food Chem* **13**: 129-137 (1984).

9 Lim M, Wu H, Breckell M and Birch J, Influence of the glass transition and storage temperature of frozen peas on the loss of quality attributes. *Int J Food Sci and Tech*, **41**: 507-512 (2006).

10 Department of Agriculture South Africa, Regulations regarding control over the sale of frozen fruit and frozen vegetables in the Republic of South Africa. *Agricultural Product Standards Act (No. 119 of 1990, R. 727),* pp. 2-8; 60-61 (1998).

11 Einstein MA, Descriptive techniques and their hybridization, in *Sensory Science Theory and Applications in Foods*, ed. by Lawless HT and Klein BP. Marcel Dekker, New York, pp. 317-338 (1991).

12 Tomic O, Nilsen A, Martens M and Næs T, Visualisation of sensory profiling data for performance monitoring. *Lebensm-Wiss Technol* **40**: 262-269 (2007).

13 Stea TH, Johansson M, Jägerstad M and Frølich W, Retention of folates in cooked stored and reheated peas, broccoli and potatoes for use in modern large-scale service systems. *Food Chem* **101**: 1095-1107 (2006).

14 Martens M, Sensory and chemical/physical quality criteria of frozen peas studied by multivariate data analysis. *J Food Sci* **51**: 599-603 (1986).

15 AOAC, 2002. *Official Methods of Analysis of* the AOAC International, 17th edition, AOAC International, Gaithersburg, MD, USA, Official method **971.29**.

16 Weatherall IL and Coombs BD, Skin color measurements in terms of CIELAB color space values. *J Invest Dermatol* **99**: 468-473 (1992).

17 Madeira AC, Ferreira A, de Varennes and Viera MI, SPAD Meter Versus Tristimulus Colorimeter to estimate chlorophyll content and leaf color in sweet pepper, *Commun Soil Sci Plan* **34**: 2461–2470 (2003).

18 Cheng M, McPhee KE and Baik B-K, Bleaching of green peas and changes in enzyme activities of seeds under simulated climatic conditions. *J Food Sci C: Food Chemistry and Toxicology* **69**: C511-C518 (2004).

19 Torregiani D, Lucas T and Raoh-Wack A-I, The pre-treatment of fruits and vegetables, in *Managing Frozen Foods* ed. by Kennedy CJ. CRC Press, Cambridge, UK, pp. 57-80 (2000).

20 Gökmen V, Baçeci KS, Serpen A and Acar J, Study of lipoxygenase and peroxidase as blanching indicator enzymes in peas: change of enzymes activity, ascorbic acid and chlorophylls during frozen storage. *Lebensm-Wiss Technol* **38**: 903-908 (2005).

21 McEwan JA and Clayton D, *Consumer perception of quality attributes of frozen peas: A qualitative approach,* Campden and Chorleywood Food Research Association, United Kingdom, Research & Development Report **71** (1998)**.**

22 Wienberg L, Martens M and Brockhoff PB, Sensory quality criteria for cold versus warm green peas studied by multivariate data analysis. *J Food Quality* **23**: 565-581 (2000).

23 Varoquaux P and Wiley RC, Biological and biochemical changes in minimally processed refrigerated fruits and vegetables, in *Minimally Processed Refrigerated Fruits and Vegetables*, ed. by Wiley RC. Chapman and Hall, New York, pp. 226-228 (1994).

24 Theerakulkait C and Barrett DM, Lipoxygenase in Sweet Corn Germ: Isolation and Physicochemical Properties. *J Food Sci* **60**: 1029-1033 (1995).

25 Bajaj KL, Dhillon GS, Nandpuri KS and Singh D, Peroxidase activity, chemical composition and plant characters of some promising pea cultivars, *Sci Hortic-Amsterdam* **9**: 1-5 (1978).

26 Megazyme, 2009. *Total starch assay procedure (amyloglucosidase/alpha-amylase method*) K-TSTA 05/06, Megazyme International Ireland Limited, Ireland.

27 Reid NB, Marks BP, Gonzalez AR and Siebenmorgen TJ, Effects of physical properties on incidence of breakage in canned white potatoes, *Am J Potato Res* **77:** 319-324 (2000).

28 Oakenfull DG, Saponins in food - A Review. *Food Chem* **6**: 19-40 (1981).

29 Bech AC, Hansen M and Wienberg L, Application of house of quality in translation of consumer needs into sensory attributes measurable by descriptive sensory analysis. *Food Qual Prefer* **8**: 329-348 (1997).

30 McCartney L and Knox JP, Regulation of pectic polysaccharide domains in relation to cell development and cell properties in the pea testa. *J Exp Bot* **53:** 707–713 (2002)