Development of Pea (Pisum sativum L.) and Chickpea (Cicer arietinum L.) Snacks using Different Cooking Methods

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Abstract

The research objectives were: to evaluate the quality of a pea snack prepared using four different methods of cooking, namely, frying, baking, steaming and microwave; to determine the effect of blending dried green pea with chickpea dhal on the quality of a fried pea snack. Green pea and chickpea snacks were prepared according to a traditional Mauritian recipe by using dried green pea and chickpea dhal respectively. Instrumental colour (CIE L*a*b*) and texture (shear force) were measured. Moisture content was determined by the air-oven drying method and fat content was quantified by the soxhlet extraction method. Quantitative Descriptive Analysis was performed by 7 experienced assessors of CFTRI using 15 cm line scales. The fried green pea snack obtained highest score for “crispy” and lowest score for “moist” texture attributes compared to the non-fried snacks ($p<0.05$). Higher instrumental shear force values were recorded for fried snacks than those which were cooked by other methods ($p<0.05$). Shear force was lowest for the steamed green pea snack (4.33±0.07 N) and highest for the fried green pea snack (20.89±0.93 N) ($p<0.05$). The CIE L* (lightness) values of the snack surface showed that the fried snacks were darker than the non-fried snacks ($p<0.05$). The fried snacks were characterised by positive CIE a*, representing red colour, with the highest value obtained for the chickpea snack (9.77±0.18) ($p<0.05$). On the other hand, the CIE a* results for the non-fried snacks were negative, representing green colour, with the lowest value noted for the steamed green pea snack (-2.33±0.44) ($p<0.05$). The fried pea snack was found to have much higher fat content than the non-fried snacks: fried snack (27.94 % w/w, wet weight basis); non-fried snacks (1.20-2.75% w/w/, wet weight basis). The reverse trend was observed for the moisture content data: fried snack (39.86% w/w, wet weight basis); non-fried snacks (45.56-68.10% w/w, wet weight basis). The sensory scores for the snack prepared with equal proportion of green pea and chickpea radiated a picture which was intermediate between the trends for the fried green pea and fried chickpea snacks. Sensory scores for “fried oil” and “onion” flavour characteristics were highest for the fried green pea snack while the fried chickpea snack obtained highest score for “pulsey” flavour and lowest score for “greenish inner core” ($p<0.05$). Significant correlations were established between sensory scores for colour and texture, as well as colour and flavour characteristics. Correlations between instrumental and sensory data for colour and texture parameters were also significant. The fried and non-fried snacks were comparable in terms of overall quality scores given by assessors.

Keywords: green pea, chickpea, snack, frying, steaming, baking, microwave cooking, sensory characteristics, quality

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1. INTRODUCTION

Mauritius has historical roots in India. Indians were brought to Mauritius by French settlers to work as indentured labourers in sugar-cane fields. The majority of the population is of Indian origin. Other ethnic groups came from Africa, China and Europe. Each ethnic group has retained its identity and cultural integration has given birth to the Mauritian culture. The traditional dishes of each ethnic group have been adopted by the population. One example of a snack of Indian origin which has become a national delicacy is the "gato pima", literally translated in English as "chilli cake". However the main ingredient is yellow pea dhal and other ingredients include salt, finely diced onions, chopped spring onions, coriander leaves and chillies. The dhal is soaked overnight, ground to a fine paste and mixed with the other ingredients. The dhal paste mixture is shaped into loose small balls and fried in hot vegetable oil until golden brown. The fried snacks are served hot with bread and butter (Mirchi, 2010). This traditional Mauritian snack is relished for its golden brown colour, crispy surface texture, soft and moist inner core as well as unique flavour. It is essentially sold by street food vendors. Interestingly, a related snack named "Massala Vala", prepared with chickpea dhal, is popular in India. In Mauritius, yellow pea dhal is imported to procure the population with the key ingredient for "gato pima". Yellow field peas (*Pisum sativum* L.) are a major pulse crop in Western Canada (Wang, Daun and Malcolmson, 2003). However, yellow pea dhal is not known in South India but dried green pea is readily available and is used mainly in curry dishes.

Pea (*Pisum sativum* L.) and chickpea (*Cicer arietinum* L.) are examples of major legumes grown in India, and constitute important sources of dietary proteins and calories. Legumes are used in three major forms: whole seeds; dehusked splits or dhals; flour (Kulkarni, 1989). Almost all the Indian traditional snack foods are prepared from cereals, legumes and spices (Ravi *et al.*, 2011). Fried legume snacks have distinctive sensory appeal. A crust is developed on the food surface, providing most of the texture, colour and flavour which impart identity and popularity to fried foods (Sahin and Sumnu, 2009). During deep-fat frying, water escapes from the food while oil migrates into the food making up to 40%

of the total mass in products like chips (Ziaiifar *et al*., 2008). Traditional fried snacks are expected to have a high fat content. India and Mauritius share similar public health problems namely diabetes and cardiovascular disease. In 2004, the national Non-Communicable Disease (NCD) survey carried out in Mauritius, revealed that one in every five adult aged 30 years and over, had type 2 diabetes, and that a number of risk factors including high serum triglyceride level remained highly prevalent (MOHQL, 2006). Fried legume snacks contribute to dietary fat intake and serum triglycerides. Dyslipidaemia, such as high levels of serum triglycerides, is a risk factor for cardio-vascular diseases and diabetes complications (MOHQL, 2006). School canteen guidelines introduced by the Ministry of Education and Human Resources in collaboration with the Ministry of Health and Quality of Life in 1995 include prohibition of the sale of fried foods as a measure towards reducing fat intake of schoolchildren and adolescents (Chan Sun, 2010). However, a national survey among public primary schools in Mauritius established that fried foods were on sale in 76.6% of schools (Chan Sun *et al*., 2009).

Strategies and actions that aim at controlling the incidence of Non-Communicable Diseases contribute to achieve food security which is defined as a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life (FAO, 2003). Thus, there is a need to reduce the fat content of traditional snacks to enhance food security as well as preserve their cultural significance. Alternative cooking methods to frying such as microwave cooking, baking and steaming could contribute to achieve this purpose. Another argument to justify research on the potential of other cooking methods to replace frying is the scientific evidence that deep fried foods might contain acrylamide, a possible carcinogen for humans (Vinci *et al*., 2012). However, the value of a cooking method depends on its effect on nutritive value, sensory properties, safety and overall quality of the food product which is a determinant of consumer acceptance. It is therefore important to validate the outcome of research on alternatives to conventional cooking methods with compositional, instrumental and sensory data. Furthermore, no systematic study has been undertaken in Mauritius to standardize and optimise the “gato pima” process to provide a scientific basis for the development of an extended shelf-life product that could be exploited commercially and exported as an “ethnic food”.

Traditional foods need to be preserved for their cultural value but fried legume snacks contribute to dietary fat intake which needs to be controlled to prevent Non-Communicable Diseases (NCDs). One strategy to reduce the fat content of snacks is to use alternative cooking methods to frying. The research and development challenge is to produce traditional healthy snacks which meet consumer sensory expectations. In this context, the research was conducted to develop pea and chickpea snacks based on the Mauritian “gato pima” process, using different methods of cooking and varying proportions of dried green pea and chickpea dhal. Legumes are used in the preparation of traditional snacks in India and Mauritius. Thus, the investigation aims at expanding the range of legume snacks available in India, and providing pioneering data for further research and development on traditional snacks in Mauritius.

The objectives of the present study were: to evaluate the quality of a pea snack prepared using four different methods of cooking, namely, frying, baking, steaming and microwave; to determine the effect of blending dried green pea with chickpea dhal on the quality of a fried pea snack.

2. MATERIALS AND METHODS

Dried green pea, chickpea dhal, sunflower oil and salt were procured from a local shop in Mysore, India. Other ingredients namely red onion, coriander leaves, spring onions and green chilli were purchased from a local market. Trial experiments were conducted using chickpea dhal and dried green pea to standardise the traditional Mauritian “gato pima” formulation and process. 200g of chickpea dhal and 325 g of dried green pea were soaked separately with twice the volume of purified water at ambient temperature for 16 hours overnight. The chickpea dhal and green pea were drained separately, weighed and blotted dry. They were used to prepare snacks using different cooking methods and proportions of pea and chickpea. Water uptake during soaking resulted in 89% and 110% weight gain for chickpea dhal and dried green pea respectively.

Preparation of green pea snacks using different cooking methods

500g of soaked green pea was ground to a homogeneous fine paste having a uniform powdery-like texture. Finely diced onion, chopped coriander leaves, spring onion and green chilli, as well as salt were added to the pea paste and mixed lightly without applying pressure to uniformly distribute the ingredients throughout the paste. 125g of pea paste mixture was transferred to inside a metal frame (20 cm (L) x 20 cm (W) x 5 mm (H)) on an oiled cutting board (25 cm x 25 cm). The paste was spread gently with a plastic spatula to obtain a uniform surface and cut into squares of 4 cm x 4 cm to obtain 25 portions. 600g of sunflower oil was heated in frying “kadai” (26 cm diameter), a traditional frying pan, to 180°C. Each pea paste portion was slided slowly into the hot oil by using a plastic spatula, and deep fried until golden brown in colour. The fried snacks were drained well between sheets of absorbent paper.

For each of the other cooking methods, 125g of pea paste mixture was shaped into uniform square portions as described for the fried pea snacks. In the case of steaming, each pea portion was individually slided into oiled idli plates using two plastic spatulas, and steamed for 10 minutes in an idli pot. For baking, the pea paste portions were gently transferred into an oiled baking tin. They were baked in a pre-heated oven at 180°C for 15 minutes. The microwaved pea snacks were prepared by sliding the pea paste portions into an oiled microwave-proof dish and cooking for 2 minutes in a microwave oven.

Preparation steps and cooking conditions were controlled to minimise variations due to factors which were not being investigated. All samples were prepared on the same day in the morning. They were held in a hot box for not more than 30 minutes before serving to assessors for sensory evaluation.

Preparation of fried green pea/chickpea and chickpea snacks

250g of soaked chickpea and remaining soaked green pea were ground separately to a fine paste. The following fried snacks formulations were prepared using the procedure described for the fried green pea snacks: equal proportion of green pea and chickpea dhal; chickpea dhal only. All samples were prepared in the afternoon on the same day. They were held in a hot box for not more than 30 minutes before serving to assessors for sensory evaluation.

Sensory evaluation

The sensory vocabulary and score cards for Quantitative Descriptive Analysis (QDA) were developed though group discussion. 12 sensory descriptors were spontaneously identified based on sensory assessment of the fried and non-fried snacks, sensory knowledge and experience. The measurement scale used was a 15 cm line scale which was anchored at 1.25 cm on either end indicated as “low” and “high” representing “recognition threshold” and “saturation threshold” respectively (Stone and Sidel, 1998). The “brown” colour descriptor line scale had anchors as “light” and “dark”. For “overall quality” the anchors were “very poor” and “very good”. Quantitative Descriptive Analysis was performed by 7 experienced assessors of Central Food Technological Research Institute, Mysore, who were briefed about the meaning of the identified sensory descriptors. The definitions were constructed from sensory knowledge and reference to Ravi et al. (2011). The colour descriptors “brown” and “green” applied to surface colour, while “greenish inner core” related to the proportion of internal green colour of snacks. “Chewy” texture has been described by ISO (2008) as “moderate level of work required to masticate a solid product in a state ready for swallowing”. Jowitt (1974) defined “firm” texture as high resistance to deformation by applied force. “Moist” mouthfeel was used to mean level of oil or moisture released from the snack while chewing. The “pulsey” flavour descriptor was identified as characteristic of volatiles derived from cooked dhal. Assessors evaluated four green pea snack samples using different cooking methods in one morning session. Fried green pea/chickpea and chickpea snacks were assessed in another session in the afternoon on the same day. One snack was served to each assessor in white porcelain dishes coded with 3-digit random numbers. The order of serving was randomised. The assessors carried out the evaluation in individual sensory booths under fluorescent lighting with the environment maintained at temperature of 20 ±5°C and Relative Humidity of 50±5%.

Instrumental measurements and chemical analysis

Surface colour readings for all samples were taken in duplicates using the Colour Measuring System, CIE LAB (view angle 10°; illumination D65). Texture was measured with a Warne Bratzler shear probe using the Texture Analyser (TA-HDi, Stable Micro Systems, Godalming, UK). Moisture content (wet weight basis) was determined by drying 5 g of snack samples in an air-oven at 100°C for 6 hours (AOAC, 1984). Fat content (wet weight basis) was quantified by the soxhlet extraction method using petroleum ether as solvent (AOAC, 1995).

Data analysis

The sensory scores were decoded, edited and processed to compute mean, standard deviation as well as generate sensory profiles using Microsoft Excel Version 2007. Further statistical analysis was applied to the sensory, moisture content, fat content and instrumental data using Statistica (version 5.5 – Stasoft, Tulsa, USA).

3. RESULTS AND DISCUSSION

Sensory profiles of green pea snacks prepared by four cooking methods show visual differences among the snack samples (Figure 1). Sensory scores for the fried snack followed a different pattern from the observed trends for the steamed, baked and microwaved snacks. The fried snack obtained higher score for "crispy" texture ($p<0.05$) than the non-fried snacks (Table 1). Instrumental texture measurements establish that the force required to shear the snack samples was higher for the fried snacks compared to the non-fried snacks ($p<0.05$) (Table 2). The data also demonstrate that the determined shear force value was lowest for the steamed green pea snack and highest for the fried green pea snack ($p<0.05$) (Table 2). Shear force is a measure of hardness of foods which has been defined by Meilgaard *et al*. (1991) as the force to attain a given deformation. Hardness and crispness are important mechanical properties of foods (Van Vliet and Primo-Martin, 2011). In the present study, crispness was quantified by trained assessors and hardness was measured instrumentally in terms of shear force. The observed crispness and hardness of fried green pea snacks could be attributed to crust formation during frying. According to Gupta (2005), one reason which makes frying a distinct process compared to other cooking methods is the extreme difference between the fryer oil and the product temperature that contributes to develop the crust and texture of the fried food. Pedreschi and Zuniga (2009) explained that surface boiling of food in hot oil during frying brings about inception of crust formation. The crust region thickens with continued frying resulting in decreased heat transfer.

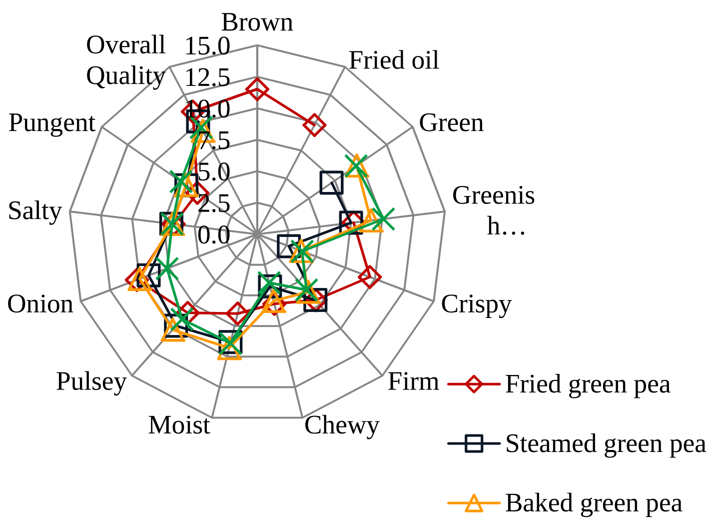

Figure 1. Sensory profiles of green pea snacks prepared using four different cooking methods

Table 1. Mean sensory scores for green pea snacks prepared using different cooking methods

	Fried (Green pea)	**Steamed (Green pea)**	**Baked (Green pea)**	**Microwaved (Green pea)**
Brown	11.52±1.19	ND	ND	ND
Fried oil	9.79±1.31	ND	ND	ND
Green	ND	7.19±0.61b	9.60±1.19a	9.55±1.56a
Greenish inner core	7.71±0.32bc	7.51±1.13cd	9.10±1.68ab	10.10±1.49a
Crispy	9.57±1.44a	2.69±0.78b	3.73±1.34b	3.82±1.68b
Firm	6.99±1.37a	6.98±0.96a	6.10±1.36a	5.90±1.99a
Chewy	5.69±1.72a	4.27±1.74a	5.45±1.56a	3.96±1.24a
Moist	6.48±0.87b	8.82±1.37a	9.30±0.37a	8.91±0.71a
Pulsey	8.33±1.57a	9.72±0.91a	10.12±0.59a	9.01±1.38a
Onion	10.22±1.90a	9.22±1.63a	9.99±1.89a	7.66±1.22a
Salty	6.68±1.37a	6.86±1.10a	6.79±0.98a	6.81±1.00a
Pungent	5.78±1.80a	6.83±1.85a	6.88±1.49a	7.36±0.74a
Overall quality	10.99±1.63a	10.10±1.55ac	9.28±2.41bc	9.58±1.35bc

Mean values in a row with different letters differ significantly ($p<0.05$) by LSD

ND: Not Detected

Table 2. Instrumental colour and texture measurements of green pea snacks prepared using different cooking methods

Samples	Instrumental colour parameters			Instrumental shear force (N)
	L*	a*	b*	
Fried (Green pea)	25.90±1.23b	5.36±0.36a	9.75±0.45b	20.89±0.93a
Steamed (Green pea)	41.87±0.22a	-2.33±0.44b	15.86±0.72a	4.33±0.07c
Baked (Green pea)	42.78±0.74a	-4.03±0.18c	16.86±1.59a	6.03±0.21b
Microwaved (Green pea)	41.23±2.81a	-5.22±0.32c	15.90±1.16a	6.98±0.84b

Mean values in a column with different letters differ significantly (p<0.05) by LSD

Table 3. Moisture content and fat content of green pea and chickpea snacks

	Samples	Moisture Content (%, w/w, wet weight basis)	Fat Content (%, w/w, wet weight basis)
Fried	**Green pea**	39.86±0.84	27.94±0.25
	Green pea /chickpea (50:50 w/w)	42.61±0.12	21.47±0.27
	Chickpea	49.79±0.24	16.83±0.21
Non-fried	**Steamed (Green pea)**	68.10±0.29	1.20± 0.01
	Baked (Green pea)	45.56±0.00	2.75±0.20
	Microwaved (Green pea)	55.89±0.51	2.12± 0.01

The fried snack obtained lowest score for “moist” texture ($p<0.05$) compared to the non-fried snacks (Table 1). The fried snacks were found to have much higher fat content than the non-fried snacks as evidenced by the quantified fat content values (Table 3). The reverse trend was noted for the moisture content data. Jowitt (1974) classified “moist” as a sensory term which relates to mouthfeel characteristics and defined it as: “possessing the textural property producing the sensation of neither an increase nor a reduction in the free fluids in the oral cavity”. According to Meilgaard *et al*. (1991) moisture properties relate to perception of water, oil, fat, measured by tactile means, and “moistness” means amount of wetness/oiliness present, when not certain whether oil and/or water. Thus, both moisture and oil/fat content of foods contribute to “moistness”. Bouchon and Aguilera (2001) stated that most fried foods are characterised by a composite structure made up of a dry, crisp and oily outer layer or crust, and a moist cooked interior or core. In the present investigation, the other cooking methods namely baking, microwave and steaming did not give rise to substantial crust formation. The presence of a dehydrated crust in the fried snack could have contributed to lower perceived intensity for “moist” texture among assessors, in contrast with the non-fried snacks.

The moisture content of the fried and baked snacks obtained in this study (Table 3) were comparable to the values for French fries (44%, wet basis) and fried eggplant cubes (50%, wet basis) presented by Ziaiifar *et al*. (2008). During the current experiment frying and baking were carried out at 180°C thereby accounting for water loss by evaporation. Gamble *et al*. (1987) stated that the frying process may be considered as a rapid combination of drying and cooking. Higher moisture content values were observed for microwaved and steamed pea snack. In the case of the microwaved snack, the shorter cooking time could have accounted for reduced water loss. On the other hand, steaming being a moist method of cooking is likely to minimise dehydration of foods during cooking.

Fat content is an important index of sensory and nutritional quality of fried foods. As expected, the fat content of fried snacks was higher than the fat content of non-fried snacks (Table 3). During frying, the oil provides an effective medium of heat transfer and is absorbed by the food (Velasco *et al*., 2009) thereby contributing to increase the fat content. The measured fat content of the fried snacks (Table 3) were less than the fat content of potato chips and eggplant cubes (40% wet basis), but within the range of published data for French fries (13% wet basis), cassava chips (25% wet basis) and tortilla chips (25% wet basis), which have been reviewed by Ziaiifar *et al*. (2008). Significant variations in fat content of fried foods are expected because several factors affect fat uptake during frying. Pedreschi and Zuniga (2009) listed the following factors: thermal and physical-chemical properties of the food and oil, the food geometry and the oil temperature.

Comparison of the sensory profiles of the non-fried snacks reveals that they were very similar (Figure 2). Statistical analysis of the sensory data further demonstrated that these samples obtained comparable sensory scores for most sensory attributes measured except for “green” colour as an appearance characteristic (Table 1). The “green” colour score for the steamed snack was significantly lower than the values recorded for the baked and microwaved snacks ($p<0.05$). Instrumental colour measurements portrayed a similar trend.

Negative a* on the CIE L*a*b* scale represents green colour (Hunter Associates Laboratory 2008). Among the non-fried green pea snacks, the green component was lowest in the steamed snacks ($p<0.05$) (Table 2). Chlorophylls namely chlorophylls *a* and *b*, are the major light-harvesting pigments in green plants. They are magnesium complexes derived from porphin (von Elbe and Schwartz, 1996). During heating of green vegetables, the acidity of plant vacuoles facilitates replacement of Mg^{2+} ion by protons to give pheophytins *a* and *b* which have a dirty brown colour (Belitz *et al*., 2004). Colour change during thermal processing of green peas due to loss of chlorophylls is well established in the literature (Coultate, 2002; Belitz *et al*., 2004). Researchers have also studied the effects of various heat treatments on the conversion of chlorophylls *a* and *b* to respective pheophytins in green vegetables including green peas (Turkmen *et al*., 2006). They found that the concentration of pheophytin *a* was highest in steamed peas followed by boiled and microwaved peas. The intensity of greenness, measured by hue angle, was reported to be highest in all microwave cooked vegetables in comparison with boiled and steamed vegetables. The authors accounted for this observation in terms of short microwave cooking time which might favour formation of other chlorophyll derivatives like chlorophyllides, which are green coloured, more than pheophytins, which have a dirty brown colour. Chlorophyllides *a* and *b* arise from the action of chlorophyllase enzyme on chlorophylls (Belitz *et al*., 2004). Mazzeo *et al*. (2011) demonstrated that steaming resulted in greater reduction in greenness of spinach than boiling. In the present investigation, loss of green colour during steaming of pea snacks could be attributed to conversion of chlorophylls to pheophytins. Possible explanations for green colour noted in microwaved snacks could be linked to microwave cooking conditions which activate chlorophyllase to produce green chlorophyllides but liberate low levels of organic acids from the plant tissue matrix thereby limiting generation of pheophytins.

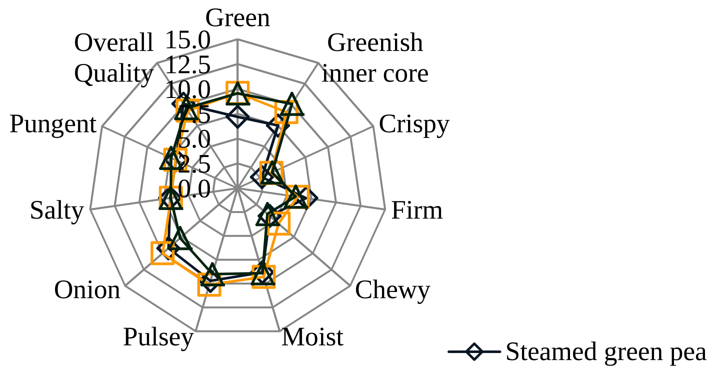

Figure 2. Sensory profiles of non-fried green pea snacks

"Brown" colour and "fried oil" aroma descriptors were identified only in the fried snack. The L* (lightness) values of the snack samples on the CIE L*a*b* scale show that the fried snack was darker than the non-fried snacks ($p<0.05$) (Table 2). According to BeMiller and Whistler (1996), common browning of foods on heating or on storage is usually due to a chemical reaction between reducing sugars and a free amino acid, called the Maillard reaction or nonenzymic browning. The Maillard reaction leads to the formation of brown pigments, known as melanoidins, and volatile compounds which are important for the desired aroma formation accompanying cooking, baking, roasting or frying, though complex reaction sequences (Belitz *et a*l., 2004). Legumes contain a large amount of carbohydrates varying from 55 to 60% and protein from 15 to 20% (Hamid Abbas El Faki *et al*., 1984). The carbohydrates in legumes are starch, dietary fibre and sugars. The main non-reducing sugars that occur in legume seeds are di- and oligo-saccharides, namely sucrose, raffinose, stachyose and verbascose. Monosaccharides, which are reducing sugars, are present in relatively small quantities (Kadlec *et al*., 2001). The protein in legume seeds is rich in lysine (Schuster-Gajzago, 2009). Side chains of lysine have been reported to be amino groups which are most often involved in the Maillard reaction (Coultate, 2002). In the present study reducing sugars and amino acids in the green pea and chickpea paste could have been the reactants in the development of non-enzymatic browning during frying. The "fried oil" aroma, detected by assessors in the fried snacks, could have originated from decomposition of unsaturated triacylglycerols contained in sunflower oil which was the frying medium in this experiment. Hydrolysis of triacylglycerols by moisture migrating from the food into the oil during frying contributes to release free fatty acids such as linoleic acid which is abundant in sunflower oil (Nawar, 1996). Belitz *et al*. (2004) explained that thermal degradation of linoleic acid produces (E,Z)- and (E,E)-2,4-decadienal which are responsible for the pleasant deep-fried flavour.

Positive a* on the CIE L*a*b* scale means red colour (Hunter Associates Laboratory, 2008). In the case of the fried green pea and chickpea snacks, the red component was highest in the chickpea snacks ($p<0.05$) (Table 4). Mittal (2009) reviewed research work on the physical properties of fried foods. He reported that redness (a*) is an inherent characteristic of fried foods which increases as frying time and temperature increases. Colour of fried foods is a determinant of quality and may also be used as an indicator of acrylamide formation during processing of foods (Lu and Zheng 2012). Gokmen and Senyuva (2006) observed similarities between changes in acrylamide and CIE redness parameter a* during heating of green coffee, wheat flour and potato chips. Their findings suggested that both acrylamide and redness form as intermediate products during Maillard reaction. Acrylamide has been classified as a “probable human carcinogen” according to international risk assessments and was found in several baked, fried and deep-fat fried foods in April 2002 (National Food Administration Sweden, 2002). Studies on acrylamide formation mechanism have provided evidence that acrylamide precursors are asparagine and reducing sugars (Vinci *et al*., 2012). Results from the European acrylamide monitoring in the period from 2007 to 2009 revealed that the major contributors to exposure for adults were “fried potatoes”, “coffee” and “soft bread” whereas for adolescents and children they were “fried potatoes”, “soft bread” and “potato crisps” or “biscuits” (EFSA, 2011). Potato products are strongly susceptible to acylamide formation because they contain the acrylamide precursors (Vinci *et al*., 2012). Alajaji and El-Adawy (2006) generated quantitative data for aspartic acid or asparagine and reducing sugars present in raw and cooked chickpea seeds. Thus, the instrumental redness of the fried chickpea snacks reported in the current study could indicate the presence of acrylamide, on the basis that acrylamide precursors are likely to be contained in chickpea and frying conditions favour the Maillard reaction.

Table 4. Instrumental colour and texture measurements of fried green pea/chickpea snacks

Samples		Instrumental colour parameters L*	a*	b*	Instrumental shear force (N)
Fried	**Green pea**	25.90±1.23c	5.36±0.36b	9.75±0.45c	20.89±0.93a
	Green pea /chickpea (50:50 w/w)	30.80±0.64b	4.61±0.16b	12.22±0.57b	17.29±0.22b
	Chickpea	33.55±0.42a	9.77±0.18a	14.90±0.36a	18.10±0.47b

Mean values in a column with different letters differ significantly ($p<0.05$) by LSD

The radar diagram for the fried snacks depicts that the snacks containing green pea only and chickpea only had definite sensory profiles (Figure 3). For many sensory descriptors, the scores for the snack prepared with equal proportion of green pea and chickpea radiated a picture which was intermediate between the observed trends for the fried green pea and fried chickpea snacks. Sensory scores for "fried oil" and "onion" flavour characteristics were highest for the fried green pea snack while the fried chickpea snack obtained highest score for "pulsey" flavour and lowest score for "greenish inner core" ($p<0.05$) (Table 5). In the case of the chickpea snacks the characteristic "pulsey" flavour of fried chickpea dhal could have contributed to mitigate the "fried oil" and "onion" flavour of the fried samples. The mean "overall quality" scores for the fried and non-fried snacks were close and ranged between "fair" and "very good".

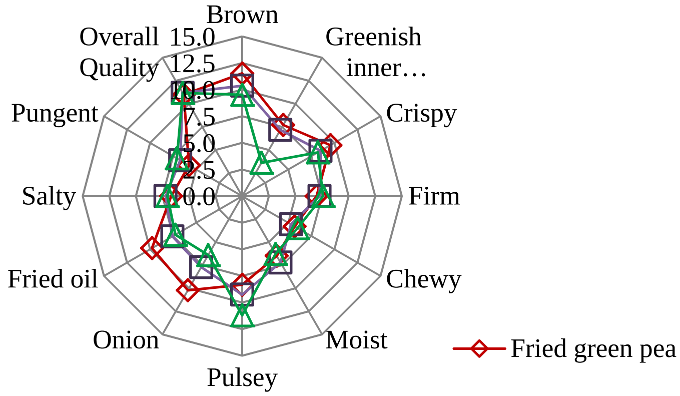

Figure 3. Sensory profiles of fried snacks prepared with different proportions and chickpea

Table 5. Mean sensory scores for fried green pea/chickpea snacks

Sensory Descriptors	**Fried**		
	Green pea	**Green pea/ chickpea**	**Chickpea**
Brown	11.52±1.19a	10.36±1.76ab	9.51±1.12b
Fried oil	9.79±1.31a	7.58±1.40b	7.26±1.65b
Greenish inner core	7.71±0.32a	6.96±0.74a	3.39±1.30b
Crispy	9.57±1.44a	8.27±0.82a	8.34±0.46a
Firm	6.99±1.37a	6.75±1.09a	7.66±1.42a
Chewy	5.69±1.72a	4.63±1.31a	6.19±0.95a
Moist	6.48±0.87a	6.84±1.10a	5.82±1.52a
Pulsey	8.33±1.57c	9.81±0.98b	11.26±0.78a
Onion	10.22±1.90a	7.89±1.13b	6.54±0.41b
Salty	6.68±1.37a	7.21±0.63a	7.15±0.45a
Pungent	5.78±1.85a	6.86±1.17a	6.97±1.48a
Overall quality	10.99±1.63a	11.20±0.87a	11.19±1.32a

Mean values in a row with different letters differ significantly ($p<0.05$) by LSD

The correlation coefficient values between the sensory and instrumental data established significant correlation between the following sensory attributes: brown and fried oil (0.952); brown and crispy (0.909); fried oil and crispy (0.917); green and moist (0.702); brown and green (-0.951); brown and moist (-0.701); fried oil and green (-0.927); green and crispy (-0.896) (Table 6). Significant correlation was also obtained for the following sensory attributes and instrumental data: brown and shear force (0.982); brown and CIE a* (0.898); fried oil and shear force (0.966); fried oil and CIE a* (0.883); green and CIE L* (0.910); green and CIE b* (0.784); crispy and shear force (0.921); crispy and CIE a* (0.771); moist and CIE L* (0.753); brown and CIE L* (-0.950); brown and CIE b* (-0.825); fried oil and L* (-0.944); fried oil and b* (-0.826); green and shear force (-0.958); green and CIE a* (-0.945); greenish inner core and CIE a* (-0.733); crispy and CIE L* (-0.869); crispy and CIE b* (-0.711); moist and shear force (-0.844); moist and CIE a* (-0.853) (Table 6). The correlation matrix indicates that brown colour scores increased in the same direction as scores for fried oil aroma and crispy texture, as well as instrumental shear force and CIE a* values (from green to red). However, brown colour scores decreased as the following parameters increased: green colour scores; moist texture scores; CIE L* (lightness) and b* (yellow) values. Green colour was positively associated with moist texture, CIE L* and CIE b* but negatively correlated with crispy texture, instrumental shear force and CIE a*. Thus, snacks which obtained high brown colour scores, also had more of instrumental red component but less of lightness and yellow components, required greater force to shear, and were perceived by assessors as having more fried oil aroma as well as crispier but less moist texture. On the other hand, snacks which obtained high green colour scores, also had more of instrumental lightness and yellow components but less of red component, required less force to shear, and were perceived by assessors as having moister but less crispy texture. Snacks which obtained high sensory scores for fried oil aroma and crispy texture, were harder to shear instrumentally, contained more of CIE redness but less of lightness and yellow components.

Table 6. Correlation matrix of sensory attributes and instrumental measurements

	Brown	Fried oil	Green	Greenish inner core	Crispy	Firm	Chewy	Moist	Pulsey	Onion	Salty	Pungent	OQ
Brown	1.000												
Fried oil	0.952	1.000											
Green	-0.951	-0.927	1.000										
Greenish inner core	-0.506	-0.494	0.668	1.000									
Crispy	0.909	0.917	-0.896	-0.485	1.000								
Firm	0.329	0.266	-0.420	-0.449	0.307	1.000							
Chewy	0.305	0.312	-0.375	-0.332	0.390	0.397	1.000						
Moist	-0.701	-0.665	0.702	0.554	-0.611	-0.257	-0.327	1.000					
Pulsey	0.002	-0.058	-0.024	-0.468	-0.054	0.041	0.022	-0.233	1.000				
Onion	-0.190	-0.121	0.263	0.473	-0.097	-0.361	0.018	0.131	-0.239	1.000			
Salty	0.105	0.135	-0.162	-0.099	0.194	0.489	0.221	0.153	-0.082	-0.142	1.000		
Pungent	-0.161	-0.183	0.127	0.003	-0.099	0.202	0.034	0.146	0.043	-0.069	0.629	1.000	
OQ	0.480	0.408	-0.500	0.448	0.440	0.655	0.236	-0.347	0.173	-0.417	0.038	-0.386	1.000
Shear force (N)	0.982	0.966	-0.958	-0.467	0.921	0.169	0.085	-0.844	-0.420	-0.130	-0.041	-0.347	0.353
L*	-0.950	-0.944	0.910	0.270	-0.869	-0.140	-0.013	0.753	0.552	0.048	-0.072	0.418	-0.357
a*	0.898	0.883	-0.945	-0.733	0.771	0.233	0.045	-0.853	-0.058	-0.319	-0.204	-0.141	0.354
b*	-0.825	-0.826	0.784	0.052	-0.711	-0.229	0.032	0.603	0.668	0.035	-0.155	0.472	-0.506

OQ: Overall Quality

4. CONCLUSIONS

Instrumental and sensory data collected in this study demonstrate that the fried green pea snack was crispier, harder and darker in colour than the snacks prepared by other cooking methods namely baking, steaming and microwave. Steaming produced a snack with lowest sensory score for green colour compared to the baked and microwaved snacks. Baking, steaming and microwave cooking effectively reduced the fat content of pea snacks. The sensory profile of fried snack prepared by blending green pea with chickpea dhal was intermediate between those of snacks containing green pea or chickpea dhal. Replacing green pea by chickpea produced a fried snack that obtained lower “fried oil” but higher “pulsey” flavour scores, and lower score for “greenish inner core”. High correlations among selected sensory parameters and instrumental measurements reflected consistent relationships between sensory scores and instrumental readings for identified colour and texture descriptors. The fried snacks were characterised by specific sensory, physical and chemical properties but were perceived as comparable to the non-fried snacks in terms of overall quality. Blending dried green pea with chickpea dhal produced a fried snack with different sensory profile but similar perceived overall quality to the fried green pea snack and the fried chickpea snack. This study provides a scientific basis for further research on the optimisation of traditional snack preparation methods and the development of healthy snack foods.

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