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Quantitative Descriptive Sensory Analysis of the Performance of Pregelatinised Starch-Protein Admixtures as Fat Mimetic in Wheat Bread

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Abstract: Quantitative descriptive sensory analysis was used to evaluate the performance of pregelatinised protein-starch admixture as fat mimetics in bread. In this work, two regimes of total fat replacements consisting of 50% protein: 50% starch admixture on one hand and 70% protein: 30% starch admixture on the other were compared to another two regimes of partial fat replacements consisting of 50% fat in composite with the above admixtures with 100% full fat bread as control to give a total of five treatments. Sensory quality was assessed by 24 trained assessors made up of 12 men and 12 females using attributes such as bread taste, crumb moistness, crust softness, cell structure, crumb and crust colours and overall acceptability. Analysis of variance revealed all treatments to be significantly different ($p<0.0001$). Principal components and cluster analyses confirmed two groupings of treatments. It is concluded that treatments with 50% fat replacement were tastier and more acceptable and resulted in significant increase ($p<0.05$) in loaf volume.

Key words: Fat mimetic, protein-starch admixture, quantitative descriptive sensory

INTRODUCTION

Many consumers are now aware of the importance of low fat diets which have gained popularity because of the increasing demand for low calorie food products by consumers (Thompson, 1990). Consumers have pressurized food manufacturers to place emphasis on the concept of diet as enhancing good health (Arvanitoyannis and van Houwelingen-Koukaliaroglou, 2005) and this has enforced the trend that more and more consumers show preference and are familiar with the consumption of dietary fibres that are known to have beneficial health effects when present in foods. To this end, a good number of food ingredients have been tried as fat replacers though their applications have been limited to baked or dairy products with a number of trials using test materials such as mono-diglycerides, micro-particulated protein, potato maltodextrin, Raftiline, Simpless C*delight and polydextrose (Armbrister and Setser, 1994; Zoulias *et al.*, 2000; Zoulias *et al.*, 2002). There has also been the introduction of a broad-based approach to fat substitution in the form of its N-LITE^{TM} line of fat substitutes for bakery, salad dressing, condiment and dairy applications and another line for low fat sausage and other meat applications (Light, 2003).

Bread is one of the major products among baked foods that is consumed worldwide in relatively large amounts (Bakke and Vickers, 2007) and is therefore likely to be a good candidate among different food systems that can act as a vehicle to incorporate food-grade fractions from grains, legumes, or other non-traditional food sources that could act as fat mimetic. A case in point is a soluble dietary fibre rich in oats and barley called ß-glucan, which is receiving attention in research circles since it lowers blood cholesterol and therefore the risk of coronary related diseases (Malkki and Virtanen, 2001). From the standpoint of reduced calories in wheat flours, hydrocolloids containing ß-glucan particularly from oats and barley have been developed into products such as 'Barleytrim' (Inglett, 1992), 'Oatrim' (Inglett, 1993) and 'Nu-TrimX' (Inglett and Carriere, 2001) have long been developed. Not only can these products add to the health benefits of ß-glucan, but they can also partially replace fat in flour based foods with heir subsequent reduction of calories.

Some researchers have tried a variety of wheat flour substitutions apart from the ß-glucan derivatives as in the application with soy and defatted soy flours with some successes (Junqueira *et al.*, 2008) as well as in applications with raw wheat germ (Sidhu *et al.*, 2001). Flaxseeds have also been used in some formulations and some promising results have been reported (Koca and Anil, 2007). There have also been reports of variable shortcomings on dough handling and bread quality when biopolymer fibres are added to wheat flour in sufficiently high amount to ensure physiological benefits associated to the significant dilution of gluten and starch that regulate the viscoelastic properties of the dough of wheat (Izydorczyk *et al.*, 2008).

Bambara groundnut [*Vigna subterranea* (L) Verdc] is among the major sources of vegetable protein in sub Saharan Africa though it remains neglected and underutilized because it has not received much research attention and is less competitive compared to other improved legumes (Lacroix *et al*., 2003). Even though blends of biopolymers such as food starch, gums and emulsifiers making up a prepackaged fat-replacement systems for baked goods are common features on the market and sound technologies also exist to firmly ensure the success of such ventures as in the case of heat-moisture treatment (Singh *et al*., 2005) which has been used to alter the physicochemical properties of starch-protein admixtures from various sources which could be employed as fat replacers in bread, quite sadly, such abundant protein and starch resource such as in bambara groundnut as well as other resources of neglected and underutilized legumes in West Africa have not been tapped the way they should.

It is believed that if research is extended to cover fat mimetics in the area of pregelatinised protein-starch admixtures, which could involve very simple technology, such fat mimetics can be incorporated into bread making to enhance its softness and other rheological properties and with the appropriate bread formulation optimization, breads with acceptable quality could be made with the addition of such non-traditional ingredients or additives.

This research hypothesises that a specific pregelatinised starch-protein admixture can be used to impart fat properties in bread. The overall aim of this study was therefore to prepare pregelatinised starch-protein-fat composite and use it as fat replacer or mimetic to fabricate wheat bread and to assess the sensory features of the fabricated bread.

MATERIALS AND METHODS

Source of raw materials: The Bambara groundnuts obtained from the Plant Genetic Resource Research Institute of the Council for Scientific and Industrial Research (CSIR/PGRRI), Bunso in Ghana for this work had proximate compositions of moisture 8.42, fat 8.97, protein 22.1, ash 3.80, fibre 3.84 and carbohydrate 52.87%. Cassava roots (accession *HO 008*) of nine months maturity were obtained from the research farms of the Biotechnology and Nuclear Agriculture Research Institute, Ghana Atomic Energy Commission (BNARI/GAEC). A 5 kg of hard flour (moisture, 11.38%, ash, 0.61%, crude fat, 1.0%, protein, 14%, fibre, 2.8% and carbohydrate, 70.21%) was obtained from Takoradi Flour Mill, Takoradi, while petroleum spirit with distillation range of 30-100°C was obtained from Tema Oil Refinery, Ghana. All other materials including; '*Pomo*' margarine, salt, sugar and ordinary dried Baker's yeast were obtained from a local market in Kumasi.

Sample preparation and extraction of proteins from Bambara groundnut: The Bambara groundnut samples were sorted to remove unwanted materials and unwholesome grains after which they were solar-dried to 12% moisture and stored in high density polyethylene bags. The dried legume grains were milled into flour using MPE roller mills (Model GP-140 Grinder) at the Biochemistry and Biotechnology Department, KNUST, Kumasi. Petroleum spirit was used to defat the coarse flour using a ratio of 1:10 w/v, with respect to flour and solvent, in a Soxhlet extractor. The defatted meal was solar dried to expel the residual solvent and stored in high density polyethylene bags. Proteins were extracted from the dried defatted meals at meal to solvent ratio of 1:10 w/v, using 0.01 M NaOH under agitation at room temperature for 2 h, in Environmental incubator shaker (New Brunswick G24) at 150 rpm according to a suggested protocol (Gomez-Brenes *et al*.,1983). The proteins and soluble polysaccharides-oligosaccharides dissolved while the insoluble polysaccharides and residues were removed by centrifuging at 2500 rpm for 20 min. The supernatant produced after centrifugation was then acidified using 0.5 MHCl to a pH range of 4.5-5.0 to allow protein precipitation after which it was centrifuged at 3000 rpm for 15 min. The precipitate was washed repeatedly with distilled water after which the precipitated proteins were freeze-dried in a HETO Power Dry LL300 and Kjeldahl analysis run (%Nx6.25) to obtain percentage protein of 94%.

Preparation of pregelatinised admixtures and baking of bread: Protein and starch admixtures were pregelatinised by the preparation of 50% aqueous slurries of protein-starch blends and poured on aluminum trays and pregelatinised in a pre-heated Ariston oven (FB51) at 115°C and heated further for 6 hrs. The pregelatinised samples were then scrapped from the aluminum trays and pulverised through 60 µm mesh. Protein and starch admixtures were composited with fat at five different levels to form blends as presented in Table 1.

Triplicates of bread dough were prepared by mixing thoroughly 500 g of hard wheat flour and either fat or fat-admixture composite (Table 1) using a formulation consisting of 5 g salt, 25 g sugar, 4 g yeast and 200 ml water as recommended recipes of bakers in Kumasi. Portions of the dough (250 g) were molded into loaves which were placed in bread pans (a loaf per pan) arranged on a flat surface, covered with high density

Table 1: Starch-protein admixture/fat composite blends

		Starch-protein admixture ratios		
Treatment	% Fat	% Starch	% Protein	Composite Fat:Admixture ratio (%)
432	100	0	0	100:0
413	50	50	50	50:50
223	0	50	50	0:100
517	50	30	70	50:50
312	0	30	70	0:100

polystyrene and allowed to rise. After 4 hrs, the dough were baked in a pre-heated traditional oven at 135°C for 30 min to stop fermentation and to solubilize the starch and to drive off alcohol and carbon dioxide and form brown crust of pleasant flavour after which the loaves were allowed to cool for 1 hr and packaged in plastic bags to control exchange of moisture. In all, five different bread samples were obtained: one 100% fat, two 50% fat: 50% admixture (one 50 proteins: 50 starch and the other 70% proteins: 30% starch) and two 100% admixture with no fat (one 50 proteins: 50 starch and one 70% proteins:30% starch) (Table 1).

Bread loaf volume: The loaf volume was measured according to the seed replacement method 10-05 of the official methods of the American Association of Cereal Chemists (AACC, 2000) with slight modification of using sunflower seeds instead of rapeseed. The volume of the loaf was then calculated using the following formula:

Vol. of loaf = container volume-sunflower seeds volume

Sensory evaluation: Quantitative descriptive analysis was used to evaluate the sensory attributes of the bread samples after 24 hrs after baking using a panel of 24 assessors made up of 12 males and 12 females who were mainly food science and biochemistry students with previous training in the use of descriptive terms. Assessors were introduced to some bread attributes descriptors using reference samples obtained from the markets as suggested by Civille and Lyon (1996). Such sensory attributes which were presented in a group discussion and adopted by the assessors were; bread-like taste, crumb moistness, crumb colour, crust softness, crust colour, cell structure and overall acceptability. These descriptors were as defined in Table 2. The assessors had a total of 6 hrs of training before the evaluation.

An unstructured scale of 15 cm line anchored at 1 cm from both ends was used for the evaluation and distances marked by panelists from the anchor points were measured and converted into scores. Sample bread pieces with dimensions 5x3x2 cm^3 were cut from each loaf of bread and served to the panel at room temperature using randomized design for serving (Stone and Sidel, 1974). In all, five samples were evaluated by each assessor. Panelists were provided with water to rinse their mouths between sampling.

Table 2: Sensory attributes and definitions adopted at the training for the assessment of bread samples in this study. Samples were actually obtained from the markets which amply described the attributes under study

Sensory Attributes	Descriptor definitions for bread samples adopted
Cell Structure	Coarse surface-Fine surface
Crust Colour	Dark brown-Yellowish brown
Crumb Colour	Dark brown-Yellowish brown
Crumb Moistness	Viscoelastic-Brittle or grainy
Crust Softness	Soft-Firm
Bread-like Taste	Characteristic bread taste
Overall Acceptability	Superior-Unacceptable

Statistical analysis of data: All data were obtained in duplicate and subjected to analysis of variance and multivariate analyses using GenStat discovery edition 3 which was used to plot a dendrogram to study closely related variates or sensory attributes. Statgraphics Centurion XV was used to identify significant difference at p<0.05 in the treatment procedures while mean separation for variance analysis was performed by using Student-Newman-Keuls test (Montgomery, 1991).

RESULTS AND DISCUSSION

Bread loaf volume: The mean volumes for each of the five reduced fat bread loaves are presented in Table 3.

Table 3: Loaf volume and mean scores of sensory attributes of bread samples using quantitative descriptive analysis over a 15 point scale*

Sensory Attributes	Bread Samples				
	223$^{\alpha}$	312$^{\beta}$	413$^{\gamma}$	432$^{\delta}$	517$^{\epsilon}$
Cell Structure[i]	8.67^{a}	7.41^{ab}	7.12^{ab}	10.30^{c}	6.13^{b}
Crust Colour[ii]	9.83^{d}	11.56^{e}	5.75^{f}	4.17^{g}	7.80^{h}
Crumb Colour[ii]	9.70^{i}	11.01^{j}	4.85^{k}	3.90^{k}	6.44^{l}
Crumb Moistness[iii]	7.59^{m}	6.09^{n}	9.98^{o}	5.38^{n}	9.35^{o}
Crust Softness[iv]	7.37^{p}	3.56^{q}	10.83^{r}	5.67^{s}	10.73^{r}
Bread-like Taste[v]	6.83^{t}	6.60^{t}	9.38^{u}	8.63^{u}	9.06^{u}
Overall Acceptability[vi]	7.23^{v}	7.73^{v}	10.14^{w}	9.94^{w}	9.80^{w}
Loaf volume (cm^3)	576	523	712	479	789

Means in a row with same superscript are not significantly different from each other. p<0.0001 for all attributes measured. $^{\alpha}$Bread sample with 100% admixture (50% protein: 50% starch) no fat; $^{\beta}$Bread sample with 100% admixture (70% protein: 30% starch) no fat; $^{\gamma}$Bread sample with 50% admixture (50% protein: 50% starch) : 50% fat composite; $^{\delta}$Bread sample with 100% fat : no admixture; $^{\epsilon}$Bread sample with 50% admixture (70% protein: 30% starch) : 50% fat composite, *Intensities scored on a 13-point line: [i]13=fine, 1=coarse; [ii]13=dark, 1 = light; [iii]13 = moist, 1 = dry; [iv]13 = soft, 1 = hard; [v]13 = high, 1 = low; [vi]13 = acceptable, 1 = unacceptable

The bread samples with 50% fat and 50% admixture (70% protein: 30% starch) (treatment 517) had the highest volume of 789 cm^3 and the sample with 100% fat (treatment 432) had the least volume measured as 479 cm^3. This is in contrast to the observations made by some researchers (Banks *et al*., 1997) who observed a significant decrease in baked volume of muffins made with added defatted soy flour. However, another school of thought has reported (Horvat *et al*., 2002) that the addition of cysteine, methionine, tryptophan and phenylalanine to non-frozen dough significantly increased the bread volume. The increase in bread volume of treatment 517 might be due to the high sulphur containing amino acids, particularly of

Table 4: Correlation among sensory attributes of bread samples

Rows	Bready T	Cell Str	Crumb Col	Crumb Moi	Crust Col	Crust Sof	Over Acc
BreadyT	1.000	-	-	-	-	-	-
CellStr	-0.201	1.000	-	-	-	-	-
CrumbCol	-0.904	-0.236	1.000	-	-	-	-
CrumbMoi	0.564	-0.746	-0.218	1.000	-	-	-
CrustCol	-0.826	-0.385	0.987	-0.105	1.000	-	-
CrustSof	0.758	-0.534	-0.501	0.930	-0.403	1.000	-
OverAcc	0.966	-0.089	-0.927	0.363	-0.861	0.569	1.000

Table 5: Latent vectors (loadings) of the sensory attributes of bread samples of the first two principal components

Sensory attributes		Latent vectors (loadings) two principal components 1	2
BreadyT	X_1	-0.2489	-0.0251
CellStr	X_2	0.01437	0.4199
CrumbCol	X_3	0.57032	-0.3031
CrumbMoi	X_4	-0.2103	-0.4844
CrustCol	X_5	0.52484	-0.3943
CrustSof	X_6	-0.4801	-0.5815
OverAcc	X_7	-0.2498	0.05392

Table 6: First two principal component scores for the five bread treatments. Sample 223 = 50% protein: 50% starch with no fat; sample 312 = 70% protein: 30% starch with no fat; sample 413 = 50% admixture (50% protein: 50% starch): 50% fat composite; sample 517 = 50% admixture (70% protein: 30% starch): 50% fat composite; sample 432 = 100% fat: no admixture (control)

Treatments	Principal component scores 1	2
223	3.396	-1.11
312	7.112	0.256
413	-5.057	-1.754
432	-2.704	5.724
517	-2.746	-3.116

methionine which is present in bambara groundnut (Temple and Aliyu, 1994). The amino acids enhanced hydrophobic interaction by probably forming disulphide cross-links probably as bridges with the wheat glutenin and gliadin to give a matrix which is more resistant to gas permeation evidenced by the volume increase (Lorient, 1974). In their work (Siddiq *et al.*, 2009) however, the bread loaf volumes decreased significantly, from 318.8-216.3 cm^3, as the defatted maize germ flour they used was increased from 0-20 g/100g because the amount of gluten, which imparts higher volume in bread loaf, was decreased as a result of gluten-free defatted maize germ flour in their bread formulations.

Descriptive sensory evaluation: Results of the descriptive sensory evaluation when subjected to a two factor analysis of variance, showed that treatment effect was significant ($p<0.05$) for all the sensory attributes tested (Table 3). In terms of bread-like taste and overall acceptability, bread samples having 50% of fat substituted (413 and 517) were not significantly different from samples having no fat substituted (432) as presented in Table 3. Generally bread samples having 50% fat substitution and those having no fat substitution were tastier and more acceptable to the panel than bread samples in which there was 100% fat substitution with protein-starch admixture. This shows the role fat plays in imparting desirable taste to bread. This observation is similar to what was observed for their study in breads replaced up to 15 g/100 g with defatted maize germ flour though the sensory overall quality scores showed a mixed trend as well with no significant differences were observed for the sensory attributes of crumb colour, cells uniformity, aroma, firmness, mouthfeel and off-flavour (BeMiller and Whistler, 1996). In terms of bread-like taste and overall acceptability, no significant difference was observed between bread samples with the partial and the complete fat substitution (Table 3). However, the presence of the admixtures contributed significantly to crust and crumb colours of the bread, with darkening of the bread crumb and crust increasing with increased protein content (Table 3). This may be attributed to Maillard reaction occurring between the amino groups of the protein and the carbonyl groups of the starch in the admixtures introduced into the bread samples (Lindsay, 1996). The higher the protein content in the bread, the more available were the amino groups to react with available aldehyde functional groups in Maillard browning reactions.

A significant increase in crust softness and crumb moistness of the bread resulted from substitution of 50% of the bread fat with the protein-starch admixtures. This may probably be due to increased water binding or hydration capacity with the introduction of the protein-starch admixture, since water molecules form hydrogen bonding with the amino groups of protein and hydroxyl groups of carbohydrate molecules. Such hydrogen bonding ensures retention of some water molecules in the bread dough during baking and thereby imparting softness and freshness to the crust and crumb. Though 100% fat substitution with 50% protein: 50% starch resulted in significant increase in crust softness and crumb moistness, the effect was lower than 50% fat substitution suggesting that fat contribute significantly to crust softness and crumb moistness or freshness.

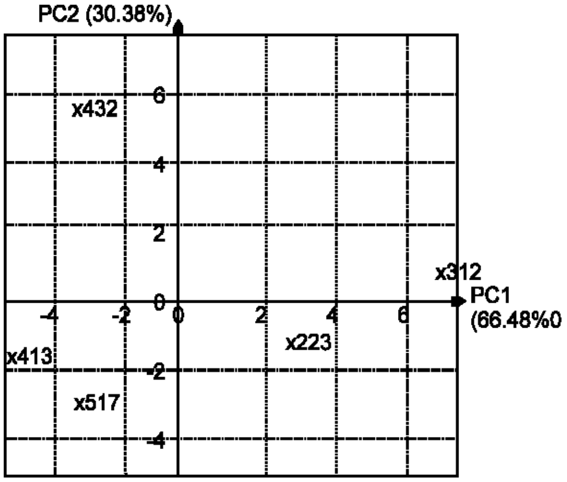

Fig.1: Scatter plot of the first two principal component scores for the five bread treatments. Sample 223 = 50% protein: 50% starch with no fat; sample 312 = 70% protein: 30% starch with no fat; sample 413 = 50% admixture (50% protein: 50% starch): 50% fat composite; sample 517 = 50% admixture (70% protein: 30% starch): 50% fat composite; sample 432 = 100% fat: no admixture (control)

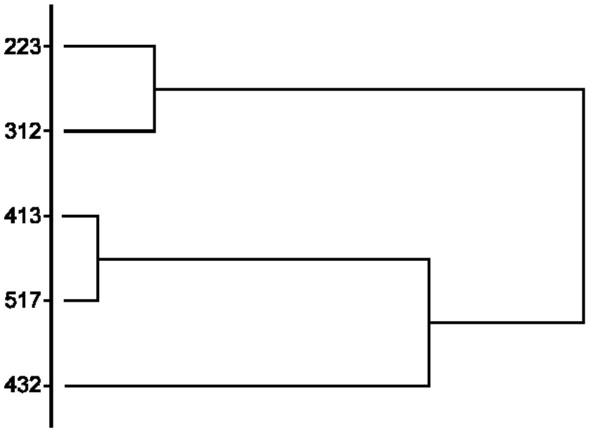

Fig. 2: Dendrogram showing clusters of similar characteristics of bread samples. Sample 223 = 50% protein: 50% starch with no fat; sample 312 = 70% protein: 30% starch with no fat; sample 413 = 50% admixture (50% protein: 50% starch): 50% fat composite; sample 517 = 50% admixture (70% protein: 30% starch) : 50% fat composite; sample 432 = 100% fat: no admixture (control)

Similarly, the defatted maize germ flour addition at 20 g/100 g was shown to have a significant negative effect on most of the sensory attributes of the bread produced giving such sensory attributes as decreased bread crust colour scores which turned from golden brown to become darker brown.

To improve the nutritional status of bread by reducing amount of fat added, it will be better replacing only 50% of fat in order to ensure that bread freshness is maintained. It has been reported (Lindsay, 1996) that fat mimetics do not posses full functional equivalency to fats but can be made to mimic the effects of fat in certain applications such as the simulation of pseudo-moistness imparted by fat to certain high-fat bakery products such as butter bread. The report further suggested that although proteins and starches can be modified to provide the desired functional properties of fat, a synergistic effect is obtained by an admixture of the two macromolecules.

Crumb texture of the bread, which was scored as cell structure, significantly decreased in fineness with substitution of the fat using the protein-starch admixtures. Bread samples having 50% fat substitution with 50% admixture comprising of 70% protein:30% starch had the highest loaf volume followed by samples with 50% fat substitution and 50% admixture comprising of 50% protein: 50% starch. Samples with no fat substitution had the lowest loaf volume (Table 3). Bread samples having all the fat substituted with protein-starch admixtures had higher loaf volumes than the samples containing 100% fat even though their loaf volumes were lower than samples having only 50% of their fat substituted with protein-starch admixtures. This implies that fat substitution with protein-starch admixture in bread generally results in increase in loaf volume. However, the effect is better with partial fat substitution than with complete fat replacement.

Sensory attribute correlations: In order to explore interactions between different quality attributes, a correlation analysis was done which gave the correlation matrix among sensory attributes of bread as presented in (Table 4) shows that bread-like taste (BreadyT) correlated highly with crumb moisture (CrumbMoi) (0.564), crust softness (CrustSof) (0.758) and overall acceptance (OverAcc) (0.966) positively just similar to their work which showed aroma in positive relationship with mouthfeel and overall quality, with correlation values of 0.987 and 0.947, respectively. The bread-like taste however, correlated strongly negatively with crumb colour (CrumbCol) (-0.904), crust colour (Crust Col) (-0.826). Cell structure (CellStr) on the otherhand highly correlated to crumb moisture (-0.746) and crust softness (-0.534) negatively. Crumb colour correlated highly to crust colour (0.987) positively whiles it correlated negatively to crust softness (-0.501) and overall acceptance (-0.927).

On the otherhand some workers have reported that crumb colour and cell uniformity correlated positively highly (0.926) and same was observed for cells

Fig. 3: Pictures showing freeze dried native bambara groundnut crude proteins (Picture 1); solar dried cassava starch (Picture 2); powdered pregelatinised protein-starch admixture (Picture 3); control bread with 100% fat (Picture 4); bread sample with 50% replaced fat replaced (Picture 5) and cell structure of bread with 50% protein: 50% starch in admixture (Picture 6)

uniformity and overall quality (0.935) (BeMiller and Whistler, 1996). These researchers also reported a highly correlated relationship between bread crust colour crumb colour (0.861) and cells uniformity (0.831) and showed a significant positive correlation (0.964) with overall quality. Crumb moisture correlated highly and positively with crust softness (0.930) but on the otherhand, crust colour correlated strongly but rather negatively (-0.861) with overall acceptance. However, crust softness had a rather weak positive correlation (0.569) with overall acceptance.

These observations show that the sensory attributes of the bread samples generally correlated among themselves and that the presence of high correlations among the seven sensory attributes in this research suggest that one can easily predict the outcome of bread sample performances when information of only a few ones are known. Also, correlations between the sensory properties of bread formulated with different ingredients would present different correlation trends as shown in this research.

Principal component analysis: Results from the principal component analysis indicate the existence of two principal components (dimensions) for the seven attributes which explain about 96.86% of the variation in the treatments. The first and second principal components accounted for 66.48 and 30.48% of the variation respectively. The analysis of the component loadings matrix in Table 5 suggest that some attributes related more closely to each other than others and this effect is the result of the contrasting groups of treatments observed in the bread samples. These sets of attributes have high loadings on the same principal component and in the same direction along the component.

The first principal component is predominantly dominated by such attributes as crumb colour and crust colour. These are the most influential sensory attributes of this component a result which confirm the findings of the correlation analysis, which also demonstrate that crumb colour and crust colour correlate most significantly with other sensory attributes. Besides, the second principal component is predominantly dominated by crust softness and crumb moisture.

A closer inspection of the linear combinations forming the first principal component, Z1 (Table 5) suggests there are two contrasts of the sensory attributes involving the cell structure, crumb colour and crust colour on one hand and that these factors were strongly sensed to correlate strongly (0.913) in all the panelists activities as can be seen in the correlated matrix of the sensory attributes (Table 4). It appears that the second principal component Z_2 is also in some kind of contrast between the cell structure and the overall acceptance on one hand and the rest of the sensory parameters on the other.

$$Z_1 = 11/10\,[(X_2) + (X_3) + (X_5)] - 11/10\,[(X_1) + (X_4) + (X_6) + (X_7)]$$
$$Z_2 = ½\,[(X_2) + (X_7)] - 13/10\,[(X_1) + (X_3) + (X_4) + (X_5) + (X_6)]$$

The values of Z_1 and Z_2 for the seven sensory attributes are known as the principal component scores presented in Table 5. Since two principal components accounted for up to 96.86% of the variation in the data, the two principal components scores can be represented in a two-dimensional scatter plot presented in Fig. 1 which shows three distinct groups of treatments which were confirmed after performing the cluster analysis as seen in the dendrogram (Fig. 2) and these groupings are (223 and 312) (413 and 517) and (432). From Fig. 1, we see that the first principal component ranks highest as the preference for treatment 312 followed by 223 on the basis of crumb colour and crust colour as a result of the high means of 11.56 and 11.06 on a 13 cm sensory scale (Table 1). The second component also tends to measure the preference for treatment 432 (control) based on the cell structure with the maximum mean value of 10.3 on a 13 cm scale.

The study has shown that replacement of fat with protein-starch admixture increases loaf volume. However, the effect is better with partial fat substitution than with complete fat replacement. When protein-starch admixtures are used as fat replacers in bread at levels above 50%, it will likely result in recognizable changes in the sensory quality of the bread.

Although several sensory attributes contribute to bread quality, overall acceptability of the bread samples studied was judged mainly based on taste. Attributes that were judged along similar lines were crust softness and crumb moistness, as well as crust and crumb colours.

It is recommended that when protein-starch admixtures must be used as fat mimetic they are used as 50% fat in combination with 50% starch: 50% protein as in formulation 413 or as 50% fat in combination with 30% starch: 70% protein as in formulation 517. Care must be taken though so that such laudable technologies would not be abused by street manufacturers who would not understand the principles involved in fat replacement technologies.

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