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RESEARCH ARTICLE

RESPONSE SURFACE METHODOLOGY ANALYSIS OF THE EFFECT OF GLUTEN AND WHEAT FLOUR ON THE TEXTURAL PROPERTIES OF VEGETABLE SAUSAGES

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ABSTRACT

Gluten and wheat flour are two important food ingredients used to influence texture of vegetable sausages. The effect of gluten and wheat flour on the textural properties of vegetable sausages was studied using response surface methodology (RSM). Vegetable sausages were prepared from soy proteins (tofu), heat-modified soy flour, gluten, wheat flour, water, xanthan gum and vegetable oil. Using different levels of gluten and wheat flour various vegetable sausages were obtained. Overlaid contour plots of textural indices were analyzed. Water absorption capacity of the ingredients (heat-modified soy flour and wheat flour) was studied. The effects of gluten and wheat flour on hardness, fracturability, springiness and chewiness were measured. The main results showed that heat-modified soy flour absorbed water more than thrice its weight as compared to wheat flour which absorbed water almost twice its weight. The RSM analysis showed that gluten and wheat flour significantly influenced the hardness, fracturability, springiness and chewiness of the vegetable sausages. Based on the overlaid contour plots, an optimum concentration of gluten (10.3%) and wheat flour (3.2%) was measured. It can therefore be concluded that the concentrations of gluten and wheat flour in vegetable sausages are very important in achieving the right texture of vegetable sausages.

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1.0 INTRODUCTION

Vegetable proteins can most extensively be found in legumes and cereals. The legume proteins are the first important class of vegetable proteins which are suitable for producing vegetable sausages (van Vliet *et al*., 2002). A typical example of this protein is soy proteins. It is well known that soy proteins contain well-balanced amino acids and they are applied in various food products such as tofu, meat extenders and vegetable sausages. Consumption of meat products have grown tremendously all over the world. In the likewise manner, people have also become more conscious about their health regarding the intake of high levels of fat and cholesterol in meat (Desmond, 2006). The demand for safe, nutritious, low fat, cholesterol-free and attractive (in texture, taste, appearance) products which lead to beneficial health effects have been on the increase (Desmond, 2006). These demands by consumers stimulate the manufacture of vegetable sausages by applying technologies and formulations which will mimic the same eating qualities of meat and furthermore meet the demands of health-conscious consumers in the world.

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The manufacture of vegetable sausages involves protein texturization and binding and stiffening of the organized protein into three-dimensional structures such as rolls and chunks (Phillips & Williams, 2011). Protein texturization involves denaturation followed by re-organization of the unfolded proteins by precipitation, aggregation or extrusion (Phillips & Williams, 2011). The texturization of soy proteins results in the formation of soy curd (tofu) which serves as a total substitute for other proteins in the vegetable sausage manufacture. The general manufacturing process of meat sausages begins with ingredient selection, grinding and mixing, stuffing and thermal processing (Marchello & Garden-Robinson, 1998). However in vegetable sausage production there is no stuffing of the product into any case. The ingredients used in the manufacture of sausages may be wet, semi-dry or dry. Tofu used should be fresh and not contaminated with microorganisms. Other ingredients can be combined in various percentages to form a mix. These may include herbs, salt, spices, flavour enhancers, antioxidants, preservatives, flavourings and colourings. Other dry ingredients such as wheat flour and soy flour act as binders (Marchello & Garden-Robinson, 1998). Wet gluten which also acts as a binder was used in this study.

Wheat gluten and wheat flour are the two important food ingredients that were used to influence texture of vegetable sausages in this research. Gluten is a viscoelastic mass and because of this cohesive property, wheat gluten has become a very important ingredient in the sausage industry influencing rheological properties such as texture, shape and expansion (Anderssen *et al*., 2004). Wheat flour is also another important ingredient needed in sausage manufacture. It basically functions as a binder and this is dependent on the starch content. When starches are heated they begin to absorb water, swell and gelatinize at certain temperatures (Fennema, 1997). Gelatinization or solubilisation of starch granules affects viscosity and overall texture of the food (Mazon, 2009). When wheat starches are used in food and cooked, the temperature affects their behaviour and when cooled, begin to thicken and gel and subsequently binding the food ingredients altogether (Mason, 2009). Texture of processed foods such as sausages is a very important attribute that conveys product quality and acceptability. Researchers have defined texture as the "sensory and functional manifestation of the structural, mechanical and surface properties of foods detected through the senses of vision, hearing, touch and kinaesthetics" (Szczesniak, 2002). Texture can either be characterized as descriptive sensory method or instrumental objective method. Instrumental texture profile analysis (TPA) is one of the common imitative tests performed to mimic the actual chewing of the teeth. Szczesniak (2002) explained that texture profiling "involves compressing the test substance at least twice and quantifying the mechanical parameters from the recorded force-deformation curve" of the texturometer. Textural properties such as hardness, fracturability, springiness and chewiness were measured from the curve. Measuring the influence of gluten and wheat flour on these textural properties of the vegetable sausages, it was imperative to use the response surface methodology (RSM) to describe the linear, interaction and quadratic effects of the factors on the response parameters. A number of researches have been conducted on the textural properties of meat sausages (Mielnik *et al*., 2002; Kerr *et al*., Wang & Choi, 2005; Garcia *et al*., 2006; Herrero *et al*., 2007). Information however on vegetable sausages is very limited. In 2007, Yang and colleagues tried to produce low fat sausages from pork by adding tofu as a texture-modifying agent. In this research tofu is the main protein isolate used for the manufacture of vegetable sausages. The objective of this research was to use RSM approach to study the effect of gluten and wheat flour on the textural properties of vegetable sausages.

2.0 MATERIALS AND METHODS

2.1 Materials

Mature grain soybeans (*Glycine max* L. Merr.), wheat flour, vegetable oil, xanthan gum and food grade magnesium sulphates were obtained from Madina market, Accra. Other materials used were wet gluten and heat-modified soybean flour.

2.2 Sample preparation

2.2.1 Soybeans

Matured grain soybeans obtained were sorted out of debris and stored at 25^{o}C.

2.2.2 Heat-modified soybean flour

Heat-modified soybean flour was obtained by soaking sorted beans overnight. Hydrated soybeans were drained, rinsed and dehulled using Straub Model 4E grinding mill (Straub Co. Phila., PA 19020, USA). The hydrated beans were shock-cooked for 30min and dried 48hrs at 50^{o}C in air oven (Genlab Limited, Tanhouse Lane, Widnes, Cheshire). The dried soybeans were then milled in a hammer mill (Christy & Norris Ltd, Chelmsford, England) and stored at 25^{o}C.

2.2.3 Wet gluten

Wet gluten was prepared by making dough and then washing the wheat dough under running water in a muslin cloth until visco-elastic mass (gluten) is formed. The gluten was either used fresh or frozen for subsequent use.

2.2.4 Tofu Production

Preparation of soymilk was done using the method described by Lim *et al*. (1990) with modifications. 500g of soybean samples were rinsed and soaked in water overnight (16 hours) at 25^{o}C. Hydrated soybeans were drained, rinsed and dehulled using Straub Model 4E grinding mill. Soybean samples were grounded with Elbee blender (LB-1222) on high speed with water for 2 min. The ratio of hydrated soybeans to water was 1:3 (solid/solvent) on weight basis. The slurry was filtered through 2 layers cheesecloth to separate insoluble materials (okara). The soymilk obtained was again filtered through 4 layers cheesecloth. Soymilk was heated to average temperature of 85-88^{o}C using LPG gas cylinder. Percentage concentration (10.4%) of magnesium sulphate coagulant was added at 85-88^{o}C and stirred for 3 s. The coagulated soymilk was left for 8 min and the soybean curd formed was transferred into a plastic strainer lined with 4 layers of cheesecloth. The cheesecloth with soy protein (tofu) samples was pressed for 30 min under a screw press to separate whey from the soy proteins. Soy protein gel was transferred into stomacher bags, sealed and stored in the refrigerator at 4^{o}C.

2.3 Sausage formulation for texture analysis

Sausage batter was prepared from soy protein (tofu), heat-modified soy flour, gluten, wheat flour, xanthan gum, water and vegetable oil. A flow chart of sausage preparation is given in Figure 1.

2.4 Design of Binding agents

A 3×3 factorial design was used to determine the effects of binding agentson vegetable sausage formulations. The levels were determined after laboratory trials. Vegetable samples were stored at 4^{o}C in the refrigerator overnight before steaming.

Levels: Gluten- 9%, 11%, 13% and Wheat flour- 3%, 4%, 5%

2.5 Water absorption capacity

Water absorption capacity of heat-modified soy flour and wheat flour were determined to study effect on texture of soybean sausage.

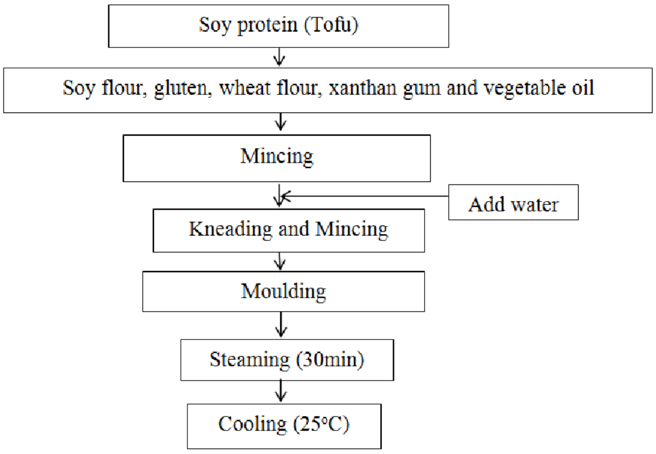


Figure 1. Flow diagram for sausage formulations for texture analysis

The method of Afoakwa *et al*. (2007) was slightly modified. 5g of sample was weighed into a centrifuge tube and 30ml of distilled water added. The mixture was stirred and allowed to stand for 30 min at 25^{o}C (laboratory bench) and 70^{o}C (in water bath) and centrifuged using a Denley centrifuge (Model BS4402/D, Denley, England), at 3000 rpm for 15 min. The supernatant was decanted and the increase in weight was weighed. The water absorption capacity was expressed as a percentage of the initial sample weight. The experiment was carried out in duplicate.

2.6 Instrumental measurements of texture

Instrumental texture profile analysis was performed by TA.XT2i Texture Analyser (Stable Micro Systems). Hardness, fracturability, springiness and chewiness of the vegetable sausage formulations were measured to determine the effect of wheat gluten and wheat flour on the sausage formulation. Samples were cut with a stainless steel blade (1.2cm height and 1.4cm diameter) for analysis. Readings were taken in triplicate with one formulation measured 10 times. The settings for the texture analyser are: compression plate (35mm diameter), Pre-test speed (2mm/s), Test speed (1mm/s), Post-test speed (2mm/s), Distance (17mm), Load cell (25kg), Temperature (25^{o}C) and Force (0.1N)

2.7 Statistical analysis

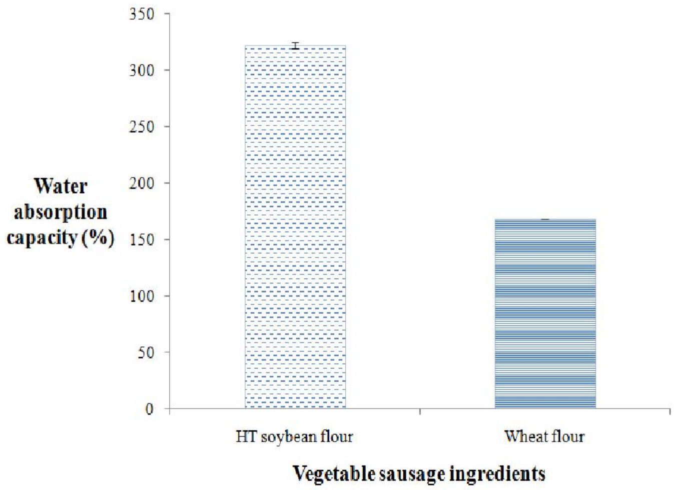
Using Statgraphics Centurion Version 15, Minitab 16 and Microsoft Office Excel 2010 software, analysis of variance and multiple range tests of the data were studied. Statistical significance was set at $p \leq 0.05$.

3.0 RESULTS AND DISCUSSION

3.1 Water absorption capacity of ingredients (heat-modified soy flour and wheat flour) used in vegetable sausage formulations

The vegetable sausages in this study were formulated mainly from tofu gels. Gelation as a functional property affected the water absorption properties of the tofu. Heat-modified soy flour and wheat flour in the formulations were mostly responsible for water absorption. The significant difference observed in the water absorption capacity (Figure 2) of the relatively high protein flours is due to the intrinsic factors: amino acid composition, protein conformation and surface polarity/hydrophobicity (Barbut 1999).

Afoakwa (1996) also affirmed that despite proteins being responsible for the bulk of water absorption, starch and cellulose to a lesser extent also absorb some of the water.



HT- Heat treated

Figure 2. Water absorption capacity of heat-treated soybean flour and wheat flour

It can be seen (Figure 2) that heat-modified soybean flour absorbed water more than thrice its weight as compared to wheat flour which absorbed water almost twice its weight. Wheat flour as stated by Wim *et al*., (2002) contains about 80 to 85% gluten proteins. These proteins show very low solubility in water as a result of the low content of amino acids with ionisable side chains and high content of non-polar amino acids (Wim *et al*., 2002). However soybean flour possesses more polar amino acids which interact much well with water (Yao *et al*., 1988) than the wheat flour proteins. The level of water absorption by the two ingredients plays a critical role in binding the sausage together. This ability greatly affected the textural properties of the final product.

3.2 Evaluating the effect of different levels of gluten and wheat flour on the textural properties of vegetable sausage formulations

Gluten and wheat flour are two important binders that are used in vegetable sausage manufacture. To obtain sausages with good binding ability that can be accepted by all consumers, this study varied the level of gluten and wheat flour to understand their effect on textural properties. A response surface methodology was thus employed to describe the linear, interaction and quadratic effects of different levels of gluten and wheat flour on the textural properties of vegetable sausages. Partial regression coefficients and their respective coefficient of determination (R^2) values of the sausages are shown in Table 1. The table indicates the textural responses: hardness, fracturability, springiness and chewiness.

Table 1. Regression coefficient, coefficient of determination (R2) of regression models for texture profile analysis of vegetable sausages from salt-based-tofu

Regression coefficients	Hardness (N)	Fracturability (N)	Springiness	Chewiness
Bo Constant	93.9*	-8	2.655	69.5*
X_1	-2010.9*	-180.8	-28.256	-1524.3*
X_2	1853*	1085.6*	15.031	1520.4*
X_1^2	7117.4*	840	30.11	4623.8*
X_2^2	-40929.4*	-14856.1*	-940.674	-38081.8*
$X_1 \times X_2$	11469*	108.8	474.217*	12528*
R^2	88.28	75.98	46.88	74.39

X_1:gluten, X_2: wheat flour
*significant at P<0.05

3.2.1 Effect of different levels of gluten and wheat flour on the hardness of vegetable sausage formulations

Three levels of gluten (9%, 11%, 13%) and also three levels of wheat flour (3%, 4%, 5%) were employed to examine their effect on the hardness of vegetable sausages using a response surface methodology (RSM) (Figure 3).

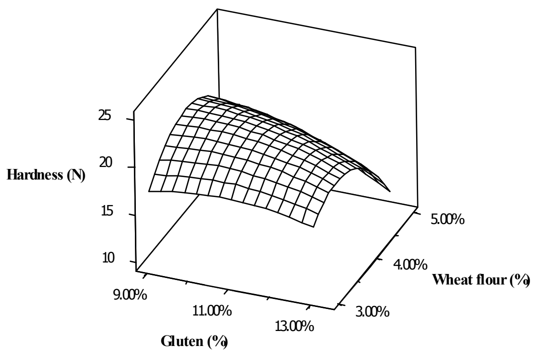


Figure 3. Contoured response surface plot for the effect of gluten and wheat flour levels on hardness of vegetable sausage formulations

Hardness is the force necessary to attain a deformation and it is recorded as the peak force on the first compression cycle (Civille & Szczesniak, 1973; Bourne, 2002). The linear effect of RSM on hardness shows that at constant wheat flour content, gluten concentration significantly influenced the trend of hardness of vegetable sausages. When wheat flour content was fixed at 3%, hardness increased from 9% (16.74N) to 11% (19.29N). Hardness however fell to 15.80N at 13% gluten. Hardness of vegetable sausages at a constant wheat flour level of 4% showed a similar trend to that observed at a fixed 3% wheat flour level. The hardness increased from 9% (19.63N) to 11% (22.07N) and finally decreased to 17.62N at 13% gluten level. Hardness of sausages at fixed 5% wheat flour content decreased significantly. At 9% gluten, hardness measured was 18.42N and decreased to 11.80N at 11%. It however increased insignificantly to 12.02N at 13%. At 9% gluten level, it can however be observed that hardness was insignificant at 3% and 5% fixed wheat flour level and also at 4% and 5% wheat flour content. The linear RSM effect of wheat flour at constant gluten was also significant.

The RSM also explained the combined effect of gluten and wheat flour in the sample. The quadratic terms of gluten and wheat flour had a significant effect on the trend of hardness observed (Figure 3). The quadratic effects between gluten and wheat flour suggested that optimum regions exist for these two factors. The optimum region for gluten was observed (Figure 3) to be 10.5-11.5% and 3.5-4.5% wheat flour.

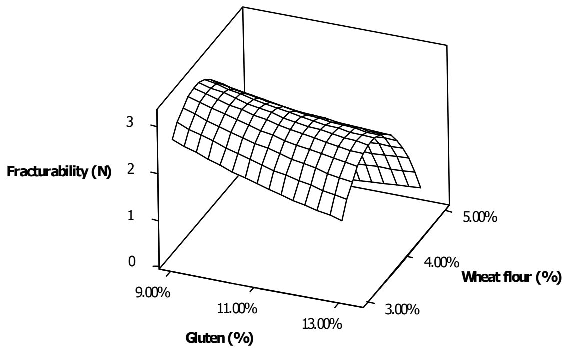


Figure 4. Contoured response surface plot for the effect of gluten and wheat flour levels on fracturability of vegetable sausage formulations

The interaction term of gluten and wheat flour shows that from 9% gluten: 3% wheat flour to 11% gluten: 4% wheat flour, hardness increased from 16.74N to 22.07N. However increasing gluten and wheat flour from 11% gluten: 4% wheat flour to 13% gluten: 5% wheat flour, hardness decreased from the maximum value of 22.07N to the minimum value of 12.02N respectively. The regression model (Table 1) could explain 88.28% of the variability in the effect of gluten and wheat flour on the sausages.

The study indicated that hardness of sausages is affected by the level of gluten and wheat flour. Gluten is a cohesive and viscoelastic concentrated protein mass which is obtained by washing the starch from dough (MacRitchie, 1984). Because of the viscoelastic property, gluten plays a vital role in sausages as a binder. Starches from wheat flour also function as a binder. The starches absorb water. When sausages are thermally treated, the heat denatures monomeric gliadins and polymeric glutenin proteins of gluten. This results in the formation of viscous structure (Kovacs *et al.*, 2004). Heat treatment also causes the starches in wheat flour to absorb water, swell and gelatinize. Gelatinization and solubilisation of starch granules and gluten's viscous structure formed as a result of the heat treatment decreases their viscosity in the sausage system. The decrease in viscosity means increment in flow properties (Belitz *et al.*, 2009) and hence as gluten and wheat flour is increased, viscous structure is also increased and more water is being absorbed and flow properties increase. As the flow properties increase, the hardness of the sausage is reduced. However at 9% gluten: 3% wheat flour to 11% gluten: 4% wheat flour, there was a rise in the hardness of sausage products. This might be due to the fact that viscous structure of gluten formed is insoluble in the presence of water (Singh and MacRitchie, 2001) and thus less water is available for wheat flour starches to absorb, swell, gelatinize and solubilize and raise the viscosity of the sausage system. This phenomenon might be responsible for the surge in the hardness of the sausages.

3.2.2 Effect of different levels of gluten and wheat flour on fracturability of vegetable sausage formulations

Fracturability refers to the ease with which a food sample crumbles cracks or shatters when a force of deformation is applied. It is a function of high degree of hardness and low degree of cohesiveness (Civille & Szczesniak, 1973). The linear, quadratic and interactive effects of gluten and wheat flour have been effectively studied (Figure 4). The linear effect of gluten at constant wheat flour (Table 1) showed no significant difference. However at constant gluten content, increasing the concentration of wheat flour will significantly influence the fracturability of the sausages. At a stable 9% gluten concentration, increasing wheat flour levels from 3% to 4% reduced fracturability from 2.82N to 2.41N respectively. At an increased wheat flour level of 5%, fracturability reduced significantly. Keeping gluten constant at 11%, fracturability increased with increasing wheat flour concentration from 3% to 4%. Fracturability was however effectively reduced at 5% wheat flour concentration. At a constant 13% gluten level, fracturability at 3% wheat flour was 1.15N. It however increased to 3.14N at 4% and finally reduced significantly to 0.09N at 5% wheat flour concentration.

The quadratic term of wheat flour significantly influenced the trend of fracturability in the vegetable sausage formulations. The presence of quadratic effect means that optimum region (3.5-4.5%) exists in the experiment. It can be observed that as wheat flour was increased from 3-4%, the fracturability also increased. However beyond 4% wheat flour content, fracturability began to decrease to the end when wheat flour reached 5%. R^2 of 75.98% of the regression model accounting for the variability in the experiment was obtained.

At increasing levels of gluten and wheat flour (starch) in vegetable sausages, viscosity is also increased. As viscosity is increased, vegetable sausages become more cohesive, consistent and interconnected. This might results in the less fragmentation and fracturability observed in the vegetable sausages with increasing gluten and wheat flour levels.

3.2.3: Effect of different levels of gluten and wheat flour on springiness of vegetable sausage formulations

Springiness shows how the vegetable sausage products return to their original shape once they have been compressed and the deforming force is removed (Civille & Szczesniak, 1973). Springiness is one important textural quality of sausages and in this study RSM was applied to investigate it (Figure 5). The springiness values in the vegetable sausage formulations were only significantly influenced (Table 1) by the interaction effect of gluten and wheat flour levels. At 9% gluten: 3% wheat flour, springiness value of 0.94 was recorded. From 9% gluten: 3% wheat flour to 11% gluten: 3% wheat flour, springiness increased from 0.94 to 1.21 respectively. The 1.21 recorded was the maximum springiness obtained. The minimum springiness (0.87) was obtained when gluten and wheat flour levels were increased to 13% gluten: 5% wheat flour. There is a positive correlation between the textural properties of hardness and springiness. Thus as hardness increases, springiness is also expected to increase and the vice versa. Also increasing wheat flour content tends to absorb more water which affects the viscosity and reduces the hardness and subsequent reduction in springiness as observed with increasing gluten and wheat flour content. Sausages can be referred to as food emulsions and therefore exhibit rheological properties such as springiness. Liu *et al*. (2013) noted that springiness is a function of product elasticity. With this property, sausages can be characterized as ideal elastic solids which are often referred to as *Hookean* solids. The elastic behaviour of sausages is related to the intermolecular forces which bonded the molecules together (McClements, 1999). When the bonds within the molecules were compressed, they stored energy and when the force was removed, the bonds relinquished this mechanical energy and the sausages returned to their original shape.

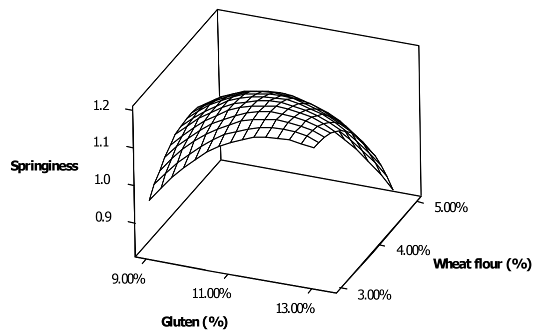


Figure 5. Contoured surface plot for the effect of gluten and wheat flour levels on springiness of vegetable sausage formulations

3.2.4: Effect of different levels of gluten and wheat flour on chewiness of vegetable sausage formulations

The effect of gluten and wheat flour levels on chewiness of vegetable sausages have been analysed (Figure 6) below. The linear, quadratic and interaction effects of gluten and wheat flour levels significantly influenced the textural properties of chewiness of the vegetable sausages. Considering the main linear effect of gluten at a constant wheat flour concentration of 3%, chewiness increased from 9% (10.14) to 11% (13.68). Chewiness however decreased to 11.28 at 13% gluten.

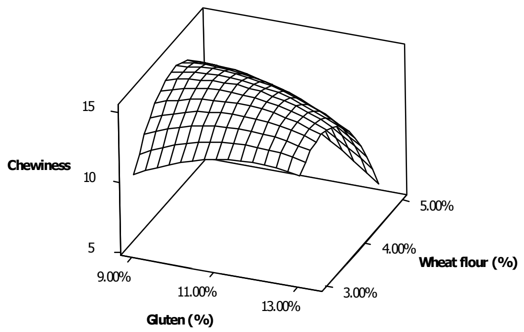


Figure 6. Response surface plot for the effect of gluten and wheat flour levels on chewiness of vegetable sausage formulations

At a constant 4% wheat flour concentration with gluten rising from 9% to 11%, chewiness increased from 12.77 to 16.43 respectively. The chewiness reduced to 12.89 at a gluten level of 13%. Another influence in chewiness was observed with increasing gluten content at 5% stable wheat flour. Chewiness decreased from (13.06) at 9% to 6.57 at 11%. Chewiness was 6.59 at 13% gluten content. The main linear effect of wheat flour at constant gluten content was also significant.

The quadratic factor term between gluten and wheat flour levels indicates that optimum region exists within the response surface plot. At the lowest interaction between gluten and wheat flour (9% gluten: 3% wheat flour), chewiness of 10.14 was recorded. Chewiness however increased to 12.76 at 9% gluten: 4% wheat flour. Chewiness remained constant at 9% gluten: 4% wheat flour through to11% gluten: 3% wheat flour. At 11% gluten: 3% wheat flour vegetable sausage formulation, the maximum chewiness value of 16.43 was measured. Chewiness however decreased with increasing gluten and wheat flour content from 11% gluten: 4% wheat flour to 13% gluten: 5% wheat flour. At 13% gluten: 5% wheat flour, the chewiness recorded was 6.59. The optimal region for the effect of wheat flour on the chewiness occurred within the range of 3.8-4.3%. From the regression model an R^2 of 74.39% was obtained and thus the model could not account for 25.61% of the variability in the data set.

According to Civille & Szczeniak (1973) chewiness is the 'energy required to masticate a solid food to a state ready for swallowing.' It is a product of hardness, cohesiveness and springiness and therefore a secondary textural attribute. Thus the trend of the chewiness observed might be influenced by the primary textural attributes that combined to produce the effect. Gluten is a cohesive protein mass (Georgopoulos *et al*., 2004) and therefore an indication of strong intermolecular bonds. At increased gluten there is more cohesiveness in the vegetable sausage system but increasing wheat flour content increased the starch component which upon heat treatment imbibed more water and reduces the hardness and cohesiveness hence the reduction of chewiness at 13% gluten: 4% wheat flour and 13% gluten: 5%

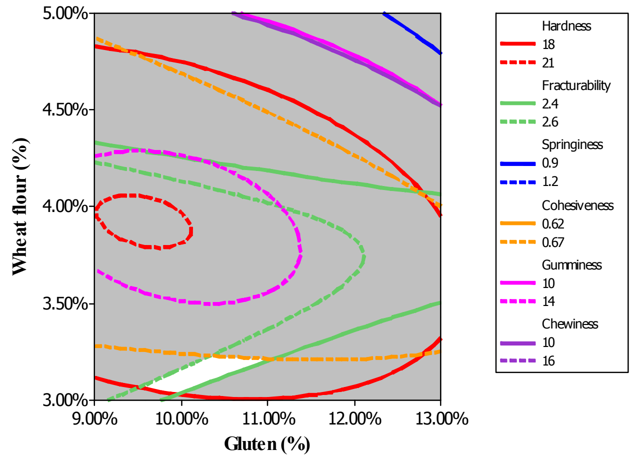
3.3 Correlation among instrumental texture indices: hardness, fracturability, springiness and chewiness of vegetable sausage formulations

Experimental results of texture parameters from TPA were used to evaluate the correlation among hardness, fracturability, springiness and chewiness (Table 2). The correlation values obtained can be used to predict the linear relationship between any two texture parameters. In Table 2, hardness was strongly correlated with chewiness (r = 0.97, p<0.05).

Table 2. Correlation matrix of instrumental texture parameters for sausages from salt-based tofu

	Ha	Fr	Sp	Ch
Ha	1			
Fr	0.72*	1		
Sp	0.77*	0.52	1	
Ch	0.97*	0.67*	0.88*	1

*significant at P<0.05



Optimum region

Figure 7. Texture contour plot of hardness, fracturability, springiness, cohesiveness, gumminess and chewiness of vegetable sausages with wheat flour and gluten as independent variables

The high correlation obtained between the two textural indices also agrees with what was obtained by Chen *et al*. (2009). Springiness is relatively high as coefficient of correlation was 0.77 (p<0.05) between hardness. Fracturability is a function of high degree of hardness and low degree of cohesiveness. Since gluten and wheat flour influenced hardness and cohesiveness, the correlation between hardness and fracturability was also influenced. The correlation coefficient calculated between hardness and fracturability was 0.72 (p<0.05). Furthermore fracturability was again not well correlated with springiness (r = 0.52, p>0.05) and chewiness (r = 0.67). Even though the correlation between fracturability and chewiness was quite low, the correlation was however significant. This therefore indicates that fracturability is independent. Even though springiness correlated significantly well with chewiness, the correlation was not above 0.90. The textural properties of vegetable sausages can therefore be grouped into three categories: 1) Hardness (Ha) or Chewiness (Ch); 2) Springiness (Sp); 3) Fracturability (Fr)

3.4: Optimization of ingredient levels (gluten and wheat flour) of vegetable sausages

Optimization of instrumental texture measurement is necessary in order to determine the optimum texture of vegetable sausages. The optimization involves an overlaid plot of texture indices (using Minitab software version 16) to determine the optimum level of gluten and wheat flour combination. Figure 7 shows the overlaid contour plots of both lower and upper limits of the textural indices (hardness, fracturability, springiness, cohesiveness, gumminess and chewiness) measured from the texture analyser. The white region indicates the optimum region. From the plot, an optimum concentration of 10.3% (gluten) and 3.2% (wheat flour) was obtained.

4. Conclusion

Wheat gluten and wheat flour influenced the textural properties of vegetable sausages studied. On the moisture absorption capacity, heat-modified soy flour absorbed most of the water in the vegetables sausages. Using the RSM, the linear, quadratic and interactive terms of wheat gluten and wheat flour concentrations significantly influenced the hardness, fracturability, springiness and chewiness of vegetable sausages. The RSM technique also proved that optimum concentrations of wheat gluten and wheat flour existed. An optimum concentration of 10.3% (wheat gluten) and 3.2% (wheat flour) was determined.

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REFERENCES

Afoakwa, E. O. 1996. Storage characteristics and quality evaluation of cowpeafortified traditional foods. B.Sc Dissertation, Department of Nutrition and Food Science, University of Ghana, Legon, Ghana, Unpublished data.

Afoakwa, E. O., Sefa-Dedeh, S., Budu, A. S., Sakyi-Dawson, E. and Asomaning, J. 2007. Influence of spontaneous fermentation on some quality characteristics of maize-based cowpea-fortified nixtamalized foods. *African Journal of Food Agriculture Nutrition and Development*,7, 1.

Anderssen, R. S., Bekes, F., Gras, P.W., Nikolov, A., and Wood, J. T. 2004. Wheatflour dough extensibility as a discriminator for wheat varieties.*Journal of Cereal Science,* 39 (2), 195–203.

Barbut, S. 1999. Determining water and fat holding. In G.M. Hall (Ed.), Methods of testing protein functionality, New York: Blackie Academic and Professional. Pp. 186-225.

Belitz, H. D.,Grosch, W. and Schieberle, P. 2009. Food Chemistry.4th Ed. Springer-Verlag Berlin Heidelberg. Heidelberg. Germany. Pg. 6.

Bourne, M. 2002. Food Texture and Viscosity: Concept and Measurement. 2nd Ed. Academic Press. Pp. 261-266, 280.

Chen, C. R., Marcotte, M. and Taherian, A. 2009. Kinetic Modeling of Texture Properties of Bologna Sausage under Cooking Conditions, *International Journal of Food Properties*, 12 (1),252-260.

Civille, G. V. and Szczesniak, A. S. 1973. Guidelines to training a texture profile panel. *Journal of Texture Studies*, 4, 204-223.

Desmond, E. 2006. Reducing salt: A challenge for the meat industry. *Meat Science*,74, 188–196.

Fennema, O. R. (Ed). 1997. Food Chemistry. Marcel Dekker, Inc. New York. Pp. 356-365.

Garcia, M. L., Caceres, E., and Selgas, M. D. 2006. Effect of inulin on the textural and sensory properties of mortadella, a Spanish cooked meat product. *International Journal of Food Science and Technology*, 41, 1207–1215.

Georgopoulos, T., Larsson, H. and Eliasson, A. C. 2004. A comparison of the rheological properties of wheat flour and its gluten prepared by ultracentrifugation. *Food Hydrocolloids*, 18, 143-151.

Herrero, A. M., Ordonez, J. A., Romero de Avila, M. D., Herranz, B., de la Hoz, L., and Cambero, M. I. 2007. Breaking strength of dry fermented sausages and their correlation with Texture Profile Analysis (TPA) and physico-chemical characteristics. *Meat Science*, 77, 331–338.

Kerr, W. L., Wang, X., and Choi, S. G. 2005. Physical and sensory characteristics oflow-fat Italian sausage prepared with hydrated oat. *Journal of Food Quality*, 28, 62–77.

Kovacs, M. I. P., Fu, B. X. Woods, S. M. and Khan, K. 2004. Thermal stability of wheat gluten protein: its effect on dough properties and noodle texture. *Journal of Cereal Science,* 39, 9-19.

Lim, B.T., Deman, J.M., Deman, L. and Buzzell, R.I. 1990. Yield and quality of tofu as affected by soybean and soymilk characteristics. Calcium Sulfate Coagulant. *J. Food Sci*., 55,1088-1092, 1111.

Lui, H. H., Chien, J. T. and Kuo, M. I. 2013. Ultra high pressure homogenized soy flour for tofu making. *Food Hydrocolloids,* 32, 278-285.

MacRitchie, F. 1984. Baking quality of wheat flours. *Advances in Food Research*, 29, 201–277.

Marchello, M. and Garden-Robinson, J. 1998. The Art and Practice of Sausage Making. NDSU-Extension service. North Dakota, USA. Pg. 5.

Mason, W. R. 2009. Starch Use in Foods. Elsevier Inc. pp. 749-750

McClements, D. J. 1999. Food Emulsions: Principles, Practice and Techniques. Chapter 8: Emulsion Rheology. CRC Press.Washington D. C. USA.

Mielnik, M. B., Aaby, K., Rolfsen, K., Ellekjæ, M. R. and Nilsson, A. 2002. Quality of comminuted sausages formulated from mechanically deboned poultry meat. *Meat Science,* 61, 73–84.

Phillips, G. O. and Williams, P.A. (Ed). 2011. Handbook of Food Proteins. Woodhead Publishing Limited. Cambridge. UK. Pp. 256, 395.

Singh, H., and MacRitchie, F. 2001. Application of polymer science to properties of gluten. *Journal of Cereal Science,* 33, 231-243.

Szcesniak, A. S. 2002. Texture is a sensory property. *Food Quality and Preference*, 13, 215-225.

van Vliet, T., Martin, A.H. and Bos, M.A. 2002. Gelation and interfacial behaviour of vegetable proteins; Current Opinion in Colloid & Interface Science. *Elsevier Science Ltd*. 7:462-468.

Wim S. Veraverbeke and Delcour, J. A. 2002. Wheat Protein Composition and Properties of WheatGlutenin in Relation to Breadmaking Functionality, Critical Reviews in Food Science and Nutrition, 42 (3), 179-208, DOI: 10.1080/10408690290825510.

Yang, H. S., Choi, S. G., Jeon, J. T. Park, G. B. and Joo, S. T. 2007. Textural and sensory properties of low fat pork sausages with added hydrated oatmeal and tofu as texture-modifying agent.*Meat Science,* 75, 283–289.

Yao J. J., Wei, L. S., Steinberg, M. P. (1988). Water-imbibing capacity and rheological properties of isolated soy proteins. *J Food Sci.,* 53(2), 464-467.

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