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QUALITY CHARACTERISTICS OF GLUTEN-FREE CHICKEN NUGGETS EXTENDED WITH SORGHUM FLOUR

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ABSTRACT

Application of coarse cereal flours is recommended to replace wheat gluten in meat products and to avoid gluten allergy in susceptible populations. Sorghum flour is a good source of dietary fiber and provides nonglutinous flours and scope for making gluten-free meat products. Keeping this in view, the present research was envisaged to evaluate the different quality characteristic of gluten-free chicken nuggets prepared with sorghum flour. Three types of chicken nuggets viz., Control chicken nuggets (CCNs), gluten-free nuggets (GFN1 with 5% sorghum flour and GFN2 with 10% sorghum flour) were compared for different physicochemical, instrumental texture, color and sensory characteristics. Use of sorghum flour significantly ($P < 0.05$) increased the product yield and dietary fiber content in GFN1 and GFN2 as compared with CCN. Instrumental color results showed that lightness (L^* value) and redness (a^*) values were significantly ($P < 0.05$) lower in GFN1 and GFN2 as compared with CCN. Texture profile analysis indicated that incorporation of sorghum flour significantly ($P < 0.05$) improved hardness, gumminess and chewiness. Sensory scores of GFN1 and CCN were significantly ($P < 0.05$) higher than GFN2. It was concluded that that 5% sorghum flour is optimum to prepare gluten-free chicken nuggets.

PRACTICAL APPLICATIONS

Sorghum is coarse millet and a popular staple diet in many developing countries. The results of this study support that sorghum flour can serve as a functional ingredient in developing healthy meat products. Use of sorghum flour in the formulation of wheat free meat products is an alternative to avoid gluten allergy. These gluten-free meat products have potential to reach the niche markets and will be highly acceptable to gluten allergic consumers who demand gluten-free products. Therefore, sorghum based food products can be marketed as health/functional products.

INTRODUCTION

Poultry meat products are important components in our diet. They are good sources of protein, essential vitamins and minerals. Poultry meat is considered to be healthier than other red meats, so there has been increased demand for poultry products. Furthermore, consumers are showing inclination towards functional meat products having extra health benefits apart from nutritional value. Therefore formulation of poultry meat products by incorporating health-enhancing ingredients like coarse cereals, green vegetables, fiber, vegetables proteins, Polyunsaturated fatty acid (PUFAs), antioxidants, etc., seems promising. Functional meat foods have added health benefits and play a role in preventing diseases by modulating physiological systems (Jimenez-Colmenero *et al.* 2001). These foods contain compounds like high fiber and anti-oxidants having health improving activities. Because of increasing concerns for health, food industries are developing new food with functional values to meet the consumer demand. Such products would open up the new market for poultry products. In this direction, it is possible to develop new meat products with potential health benefits by increasing or introducing bioactive ingredients. Among different strategies to produce healthier meat products re-formulation is one of the best method, most practical, viable and effective strategy (Arihara 2006). This reformulation of meat products can be done by incorporating health-enhancing ingredients such as coarse cereal flours, green vegetables, fiber, vegetables proteins, PUFA, antioxidants, etc.

Wheat gluten is one of the most commonly used ingredients in meat products. However gluten allergy in susceptible population has been increasing in recent years. Jackson *et al.* (2006) reported the use of rice starch in the formulation of low-fat, wheat-free chicken nuggets. They found that wheat-free chicken products have the potential to reach the niche markets and will be highly acceptable to consumers allergic to gluten who demand gluten-free products. Therefore, application of other cereal flour is recommended to replace wheat gluten (Handoyo *et al.* 2008).

Sorghum provides nonglutinous flours and scope for making therapeutic diet for people suffering from gluten enteropathy and gluten allergy. Sorghum is coarse millet and a popular staple diet in many developing countries. Sorghum is a rich source of phenolic compounds, phenolic acids, flavanoids, tannins and dietary fiber (Dykes and Rooney 2006). Sorghum flour (SF) has water retention and fat absorption properties. Using SF as an extender or filler will reduce fat content in meat products and may improve texture and yield of finished products. In addition, SF is rich in dietary fiber, low in fat, which gives it the functional characters required in health foods. Extension of ground beef patties with 2, 4 and 6% SF was reported by Jen *et al.* (1999). They reported that patties having SF had higher pH, greater yield, color and textural, sensory properties and less shrinkage. They further found that addition of SF increased retention of fat and water and decreased Hunter redness value, shear force and compression values. They concluded that SF can be effectively used as extender in the meat products with out affecting the sensory properties. Effect of 2–5% levels of SF on quality characteristics of frankfurters was reported by Van Zyl and Setser (2001). They observed that inclusion of 2, 3.5 or 5% SF in frankfurters had no significant influence on pH, viscosity or thermal stability of batters. Further they found that the level of SF had no effect on proximate composition, mechanical, sensory or shelf-life measurements. They concluded that up to 5% SF can be used in frankfurters without adverse effects. Similarly Kumar *et al.* (2007) compared the SF with corn and wheat flours for use in chicken nuggets. These studies indicate that SF can serve as functional ingredient in developing healthy meat products.

Therefore this study was planned to evaluate the quality characteristics of gluten-free chicken nuggets prepared by incorporating SF.

MATERIALS AND METHODS

Three types of chicken nuggets were compared for different physicochemical, instrumental texture, color and sensory characteristics. These nuggets were designated as Control chicken nuggets (CCNs), gluten-free nuggets (GFN1) and GFN2. The formulation for all three nuggets was similar except that: (1) CCNs contain refined wheat flour (5%), but no SF; (2) GFN1 contain 5% SF in place of wheat flour; and (3) GFN2 contain 10% SF replacing 5% wheat flour and 5% meat in control nuggets. Other all ingredients were similar for three types of chicken nuggets. The proximate composition (%) of SF consisted of: moisture = 11.9; protein = 10.4; fat = 1.9; fiber = 1.6; carbohydrate = 72.6; and minerals = 1.6.

Materials and Preparation of Chicken Nuggets

Spent hen meat obtained from University poultry farm was deboned, chilled overnight (4±1C), ground twice through 8 mm plate and used for meat nuggets preparation. Freshly prepared wheat flour and SF were obtained from local super market. Sodium chloride, sodium tripolyphosphate, sodium nitrite, spice mix, egg liquid, condiments (onion and garlic paste) and refined sunflower oil were other ingredients used for the preparation of chicken nuggets. Meat emulsion was prepared by blending meat with other ingredients as per the formulation. This emulsion was manually filled in stainless steel molds (about 450 g) and lids of the mold were tightly closed. The molds were steam-cooked to an internal temperature of 80–82C. Internal temperature of blocks was measured with a digital thermometer having a probe. After, internal temperature reached the 80–82C, blocks was held at this temperature for 15 min. After this thermal process meat blocks were cooled to room temperature. Nuggets of uniform size were prepared from these cooked blocks and used for analysis and sensory evaluation.

pH, Emulsion Stability, Cooking Yield and Proximate Analysis

The pH of the nuggets was determined by blending sample with 50 mL distilled water for 60 s in a homogenizer. The pH values were measured using a standard electrode attached to a digital pH meter (Century Ltd., New Delhi, India). Emulsion stability was calculated by recording the weight loss of 50 g emulsion during thermal processing in a water bath at 82C for 25 min (Youssef and Barbut 2009). Cooking yield was determined by dividing cooked product weight by the raw product weight and multiplied by 100. Ground samples of cooked chicken nuggets were analyzed for moisture (oven air-drying method), fat (Sohxlet method), protein (Kjeldhal method), ash (muffle furnace) and dietary fiber according to AOAC (2000) procedures. All determinations were performed in duplicates.

Instrumental Color Evaluation

Instrumental color of nuggets was measured as described by Conforth (1994) using a Hunter Lab Miniscan Spectrocolorimeter; model 4,500 L (Hunter Lab Inc. Reston, VA) with 25 mm aperture set for illumination D65, 10° standard observer angles. *Commission Internationale de l'Éclairage* L^* (lightness), a^* (redness) and b^* (yellowness) were measured on the cut surfaces of nuggets from four randomly chosen spots. Hue and chroma were calculated by using formulae, hue = $(\text{Tan} -1b^*/a^*)$ and Chroma = $(a^{*2} + b^{*2})^{1/2}$.

Texture Profile Analysis (TPA)

Cooked nuggets were evaluated for instrumental TPA (Bourne 1978). A Stable Microsystems Texturometer (Stable Microsystems Ltd., Surrey, U.K.) model TA-XT_2 texture analyzer attached with software, texture expert was used for TPA analysis. Six cooked nuggets from each group were compressed twice to 50% of their original height. The parameters determined were: hardness (N) = maximum force required to compress the sample, gumminess (N) = force to disintegrate a semisolid meat sample for swallowing (hardness × cohesiveness), chewiness (Ncm) = work to masticate the sample for swallowing (springiness × gumminess), cohesiveness = extent to which sample could be deformed prior to rupture (A2/A1, A2 being maximum force required for the first compression and A2 being maximum force required for second compression), and springiness (cm) = ability of sample to recover to its original shape after deforming force was removed.

Sensory Evaluation

Eight to 10 experienced sensory panellists initially were trained and selected after five 1-h training sessions to recognize sensory attributes: color, flavor, juiciness and texture. The panelists rated each sample for color, flavor, juiciness and texture on an 8-point descriptive scale (Keeton *et al.* 1984). An 8-cm line anchored at both ends (0 = very poor to 8 = excellent) was used to score the intensities of attributes. The results were converted into numerical values by measuring the distance of the line from the left (0) to the right (8) end. Warm and coded samples were served under a combination of daylight and neutral white light. Water was served for cleansing the mouth between samples.

Statistical Analysis

Entire experiment was repeated thrice and duplicate samples for each parameter were analyzed to get a total number of six observations ($n = 6$) for each parameter. All parameters were analyzed by one-way analysis of variance using SPSS (SPSS version 13.0 for Windows, SPSS, Chicago, IL). The least significant difference was calculated at $P < 0.05$.

RESULTS AND DISCUSSION

The effects of incorporating SF on physicochemical and proximate composition are presented in Table 1. The pH did not vary significantly between three types of chicken nuggets. Emulsion stability was significantly ($P < 0.05$) higher in GFN1 and GFN2. Use of SF significantly ($P < 0.05$) increased the product yield in GFN1 and GFN2 as compared with CCN. It is reported that SF enhanced the three-dimensional structure of the meat system with starch and plant protein gels entrapping fat and water (Jen *et al.* 1999). Therefore increased emulsion stability and the product yield in GFN1 and GFN2 might be attributed to retention of water and fat by SF. Proximate analysis showed a significant difference ($P < 0.05$) in moisture and dietary fiber content of three types of nuggets. GFN1 had highest moisture followed by CCN. GFN1 and GFN2 had significant ($P < 0.05$) higher amount of dietary fiber as compared with CCN. This could be caused by higher content of dietary fiber in SF as compared with refined wheat flour. It has been reported that SF is a rich source of complex carbohydrates and dietary fiber (Rooney and Awika 2005). This functional property is reflected in GFN, which contain higher amount of dietary fiber. Fat, protein and ash content of different nuggets did not show significant difference among three types of nuggets. Jen *et al.* (1999) reported that beef patties formulated with 2, 4 and 6% SF showed higher pH,

TABLE 1. EFFECT OF SORGHUM FLOUR ON PHYSICOCHEMICAL AND PROXIMATE COMPOSITION OF CHICKEN NUGGETS

Type of nuggets	pH	Emulsion stability (%)	Yield (%)	Moisture (%)	Fat (%)	Protein (%)	Ash (%)	Dietary fiber (%)
CCN	5.95	91.76a	92.63a	61.20b	9.12	20.29	3.51	1.37a
GFN1	5.98	93.86b	94.99ab	63.73c	8.48	20.08	3.40	2.72b
GFN2	5.97	93.73b	96.24b	59.84a	9.14	19.32	3.43	2.28b
Mean standard error	0.01	1.37	0.65	0.53	0.24	0.25	0.06	0.20

Note: Number of observations = 6. Mean values in the same column bearing the same superscripts do not differ significantly ($P < 0.05$).
CCN, control chicken nugget; GFN1, gluten-free nuggets with 5% sorghum flour; GFN2, gluten-free nuggets with 10% sorghum flour.

TABLE 2. EFFECT OF SORGHUM FLOUR ON HUNTER COLOR VALUES OF CHICKEN NUGGETS

Type of nuggets	*L**	*a**	*b**	Hue	Chroma
CCN	50.18b	8.64b	11.80	53.67a	14.63
GFN1	50.02ab	7.16a	11.82	56.03b	14.26
GFN2	45.54a	7.47a	11.55	56.35b	14.11
Mean standard error	0.58	0.22	0.10	1.08	0.41

Note: Number of observations = 6. Mean values in the same column bearing the same superscripts do not differ significantly ($P < 0.05$).
CCN, control chicken nugget; GFN1, gluten-free nuggets with 5% sorghum flour; GFN2, gluten-free nuggets with 10% sorghum flour.

yield and less shrinkage. They further found that SF increased the retention of fat and water in beef patties. Our findings are similar to the results of Huang and Zayas (1992) who added corn flour to ground beef patties and found decreased total cooking loss and increased cooking yield. However, Van Zyl and Setser (2001) reported that three levels of SF (2, 3 and 5%) did not have significant effect on pH and thermal stability of frankfurters. They also found that three levels of SF did not affect significantly the proximate composition of frankfurters.

Instrumental color evaluation results are given in Table 2. Redness (a^*) values were significantly ($P < 0.05$) lower in GFN1 and GFN2 as compared with CCN. Overall lightness (L^* value) was significantly ($P < 0.05$) reduced by addition of 10% SF. However no significant difference was observed in overall brightness between CCN and GFN1.Values for yellowness (b^* value) were not affected by addition of SF. Hue angle was significantly ($P < 0.05$) higher in GFN1 and GFN2 as compared with CCN. But chroma values were not affected by addition of SF in chicken nuggets. It has been reported that SF contains anthocyanins and tannins that produce dark-colored products (Dykes and Rooney 2006). Similar to above-mentioned findings, Jen *et al.* (1999) and Van Zyl and Setser (2001) reported that redness (a^*) of beef patties and frankfurters decreased with increase in the level of SF. They further observed an increase in Hue angle in SF containing frankfurters and no difference for chroma (saturation index) values in different frankfurters.

Results of TPA (Fig. 1) indicated that incorporation of 10% SF significantly ($P < 0.05$) increased hardness in GFN2. But CCN and GFN did not show any significant difference for hardness. Similarly gumminess and chewiness were also significantly ($P < 0.05$) higher in GFN2 as compared with GFN1 and CCN. SF has high water and fat absorption properties and helps meat protein to form a three-dimensional structure by gelatinization of protein and starch. Furthermore TPA showed that springiness significantly decreased because of 10% SF in GFN2. However cohesiveness of different nuggets did not differ significantly. Over all results of texture evaluation showed that addition of 5% SF did not affect significantly the textural parameters of gluten-free chicken nuggets. Peng *et al.* (1982) reported that plant protein acts as a diluent to reduce interaction among myosin heavy chains of animal proteins and thereby reducing firmness of the three-dimensional structure but yet entrap water and fat. Similar to our findings, Van Zyl and Setser (2001) reported that use of 2–5% SF did not have significant effect on adhesiveness and firmness of frankfurters. In contrast, Jen *et al.* (1999) found that textural parameters increased with increased levels of SF in beef patties. They further noticed that increased level of SF decreased the shear force and compression values of beef patties.

Results of sensory evaluation (Table 3) showed that scores for all sensory parameters were significantly lower in GFN2 than GFN1 and CCN. Decreased color scores in GFN2 might be caused by decrease in redness (Hunter a^*) as indicated by instrumental color evaluation. Addition of 10% SF masked

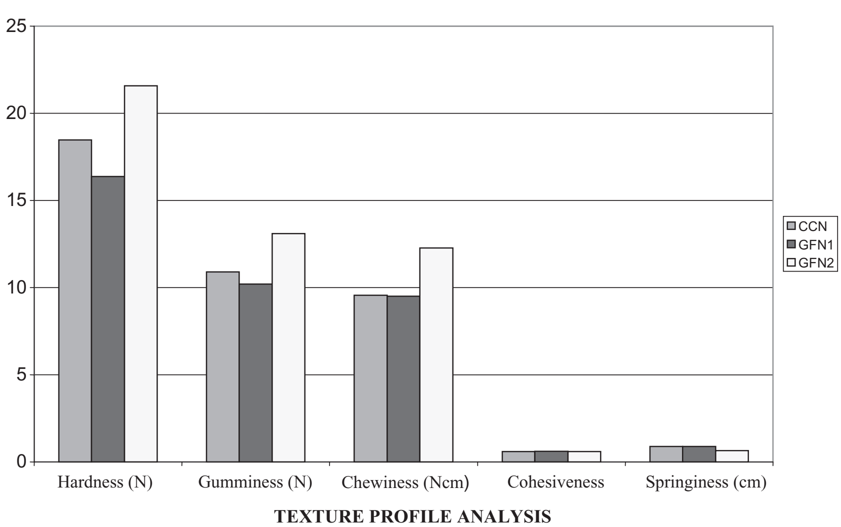

FIG. 1. EFFECT OF SORGHUM FLOUR ON TEXTURAL QUALITIES OF CHICKEN NUGGETS
CCN, control chicken nugget; GFN1, gluten-free nuggets with 5% sorghum flour; GFN2, gluten-free nuggets with 10% sorghum flour.

TABLE 3. EFFECT OF SORGHUM FLOUR ON SENSORY SCORES OF CHICKEN NUGGETS

Type of nuggets	Color	Flavor	Juiciness	Texture
CCN	7.33b	7.25b	7.25b	7.17b
GFN1	6.85b	7.00b	7.17b	7.17b
GFN2	6.25a	6.33a	6.42a	6.42a
Mean standard error	0.14	0.22	0.10	0.15

Note: Number of observations = 24. Mean values in the same column bearing the same superscripts do not differ significantly ($P < 0.05$). A score of 8 indicates the highly acceptable (excellent) sensory quality and 1 indicates unacceptable (very poor) sensory quality.

CCN, control chicken nugget; GFN1, gluten-free nuggets with 5% sorghum flour; GFN2, gluten-free nuggets with 10% sorghum flour.

the intensity of chicken flavor and decreased firmness in GFN2. Sensory panelists noticed decreased chicken flavor and firmness in GFN2, which scored significantly less ($P < 0.05$) during sensory evaluation. Keeton *et al.* (1984) found that wheat flour contributed some off-aroma and off-flavor to frankfurter formulations. Gnanasambandam and Zayas (1994) found similar results with wheat flour, which reduced firmness of frankfurters. Juiciness scores of GFN2 were also significantly lower than CFN and GFN1. Possibly, addition of 10% SF did not retain enough of the added water to be detected as juiciness by sensory panellists. Sensory scores of GFN1 and CCN did not vary significantly. Sensory panelists rated GFN1 and CFN as equal for all sensory attributes. This indicated that 5% SF is optimum to prepare gluten-free chicken nuggets. Jen *et al.* (1999) observed higher sensory scores for beef patties prepared with 2–6% of SF. Van Zyl and Setser (2001) found that addition of SF (2–5% levels) did not affect the sensory properties of frankfurters. They concluded that these levels of SF can be effectively used as extender in meat products without affecting the sensory characteristics.

CONCLUSIONS

SF is a major staple food in semi-arid countries. This study showed that 5% SF could be effectively incorporated in the preparation of gluten-free chicken nuggets with out affecting the qualities. Incorporation of SF in chicken products can be suggested to prepare healthy and functional meat products.

REFERENCES

AOAC 2000. *Official Methods of Analysis*, 16th Ed., Association of Official Agricultural Chemists, Washington, DC.

ARIHARA, K. 2006. Strategies for designing novel functional meat products. Meat Sci. *74*, 219–229.

BOURNE, M.C. 1978. Texture profile analysis. J Food Sci. *32*, 62–67.

CONFORTH, D. 1994. Color: Its importance. In *Quality Attributes and Their Measurements in Meat, Poultry and Fish Products. Advances in Meat Research*, Vol. *9* (A.M. Pearson and T.R. Duston, eds.) pp. 34–78, Blackie Academic and Professional, Glasgow, U.K.

DYKES, L. and ROONEY, L.W. 2006. Sorghum and millet phenols and antioxidants. J Cereal Sci. *44*, 236–251.

GNANASAMBANDAM, R. and ZAYAS, J.F. 1994. Quality characteristics of meat batters and frankfurters containing wheat germ protein flour. J Food Qual. *17*, 129–142.

HANDOYO, T., AKAGAWA, M., MORITA, N., MAEDA, T. and MITSUNGA, T. 2008. Hypoallergic characteristics of wheat flour produced by stepwise polishing. Int J Food Prop. *11*, 243–252.

HUANG, S.C. and ZAYAS, J.G. 1992. Protein solubility, water retention, and fat binding of corn germ protein flour compared with milk proteins. J Food Sci. *57*, 372–376.

JACKSON, V., SCHILLING, M.W., COGGINS, P.C. and MARTIN, J.M. 2006. Utilization of rice starch in the formulation of low-fat, wheat free chicken nuggets. J Appl Poultry Res. *15*, 417–424.

JEN, C.H., ZAYAS, J.F. and BROWERS, J.A. 1999. Functional properties of sorghum flour as an extender in ground beef patties. J Food Qual. *22*, 51–61.

JIMENEZ-COLMENERO, F., CARBADO, J. and CARBADO, S. 2001. Healthier meat and meat products: Their role as functional foods. Meat Sci. *59*, 5–13.

KEETON, J.T., FOEGEDING, E.A. and PANTANA-ANAKE, C. 1984. A comparison of nonmeat proteins, sodium tripolyphosphate and processing temperature effects on the physical and sensory properties of frankfurters. J Food Sci. *49*, 1462–1465.

KUMAR, R.R., SHARM, B.D., MANISH, K., CHIDANANDAIAH and BISWAS, A.K. 2007. Storage quality and shelf life of vacuum packaged chicken patties. J Muscle Foods. *18*, 253–263.

PENG, I.C., DAYTON, W.R., QUASS, D.W. and ALLEN, C.E. 1982. Studies on the subunits involved in the interaction of soybean 11 protein and myosin. J Food Sci. *47*, 1984.

ROONEY, L.W. and AWIKA, J.M. 2005. Overview of products and health benefits of specialty sorghums. Cereal Foods World. *50*, 1199–1221.

VAN ZYL, H. and SETSER, C.S. 2001. Measuring characteristics of frankfurters extended with sorghum flour. J Food Qual. *24*, 37–52.

YOUSSEF, M.K. and BARBUT, S. 2009. Effect of protein level and fat/oil on emulsion stability, texture, microstructure and color of meat batters. Meat Sci. *82*, 228–233.