International Journal of
Food Science & Technology
www.ifst.org

International Journal of Food Science and Technology 2011, **46**, 122–129

Original article

Effect of banana and soybean hull flours on vacuum-packaged chicken nuggets during refrigeration storage

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(Received 26 June 2010; Accepted in revised form 15 September 2010)

Summary The green banana flour (GBF), soybean hull flour (SHF) and combination (50:50) of GBF and SHF were added at the level of 4% each to evaluate the storage characteristics of chicken nuggets. The pH values were declined ($P < 0.05$) over storage periods. Lipid oxidation products were higher ($P < 0.05$) in control samples; however, they were increased in all samples with the increase in storage time. GBF-added samples had lower ($P < 0.05$) free fatty acid contents when compared to other treated nuggets including control. With respect to microbial quality, standard plate counts, psychrotrophic counts and *Lactobacillus* spp. counts were increased ($P < 0.05$) with the storage periods. Total coliforms, *Staphylococcal* spp. and Yeast and mould counts were detected sporadically. Result of sensory evaluation indicates that scores for all attributes were declined gradually with storage time, and slight off-flavour was noticed on the day 45. So, chicken nuggets developed with GBF and SHF could have shelf life in between 36 and 45 days at 4 ± 1 °C under vacuum-packaging conditions.

Keywords Green banana flour, lipid oxidation, nuggets, soybean hull flour, vacuum packaging.

Introduction

In the recent years, scientific evidence confirming the relationship between food and health promoted the rapid development of new food market, the functional food market (Viuda-Martos *et al*., 2010). The functional food products are generally produced by the reformulation of meat by incorporating health-producing ingredients such as fibres (Hur *et al*., 2009), proteins (Fernandez-Gines *et al*., 2005), prebiotics (Wang, 2009), probiotics (Vuyst *et al*., 2008), polyunsaturated fatty acids (Clough, 2008) and antioxidants (Eim *et al*., 2008). The inclusion of fibres in meat system improves functional properties through their solubility, viscosity, gel-forming ability, water-binding capacity, oil adsorption capacity and mineral- and organic molecule-binding capacity, which affects product quality and characteristics (Tungland & Meyer, 2002). Beside these, high-fibre, low-fat foods tend to reduce risk of colon cancer, obesity, cardiovascular diseases and several other disorders (Schneeman, 1999). However, because of imposition of new food laws concerning the health claims and vast regional differences in the consumption of functional foods, growth opportunities remain in the global health market as scientific studies remain uncovered the benefits of both emerging and existing ingredients (Viuda-Martos *et al*., 2010). Soybean hull flour (SHF) contains up to 19.2% crude protein and 50% dietary fibre (Batajoo & Shaver, 1998) while green banana flour (GBF) contains about 3.2% protein, 1.3% fat, 3.7% ash and 14.0% dietary fibres (Pacheco-Delahaye *et al*., 2008). A distinctive characteristic of the soy polysaccharides improves textural property through water-binding capacity (Lai *et al*., 2003). The texture of the product is directly related to bulk density, because light density means soft structure which is desirable in such product type (Koksel *et al*., 2004). As soy hull increased, its fibre competes for water increasing the viscosity, which causes less shrinkage when added in meat products. Antioxidant property of soy protein fractions is well documented (Das *et al*., 2008). GBF is rich in fibres as well as other nutrients such as vitamin C and A, glutathione, flavonoids and phenolics (Suntharalingam & Ravindran, 1993). The water absorption property of banana flours depends on the degree of intermolecular bonding, while swelling power and solubility are temperature dependent, as starch molecule depolymerised by the thermal treatment (Alexander, 1995). The banana flour starts to gel formation at

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doi:10.1111/j.1365-2621.2010.02461.x

the initial pasting temperature of 63 °C. However, functional property of GBF in meat system still needs to be elucidated (Suntharalingam & Ravindran, 1993).

It has been observed that lipid oxidation is one of the most important factors affecting the quality of precooked meat products during refrigeration storage (Ciz *et al*., 2010). Lipid oxidation in meat products is initiated when polyunsaturated fatty acids (PUFA) react with molecular oxygen, via free radical chain mechanism, forming peroxides (Eim *et al*., 2008). Myoglobin oxidation causes discolouration which influences consumer acceptance. Haem pigments, in meat brought contact with lipids, are strong oxidation catalysts (Erickson, 2002). However, fatty acid composition of the phospholipids in the muscle cell membranes is especially an important factor in determining the stability of meat, because oxidative changes are initiated from the membrane components of muscle. Effective packaging could maintain products quality, but usage of polyethylene (PE) bags may result in reduced shelf life of meat products because of increased fat oxidation and moisture absorption rate, in comparison with products in vacuum bags (Summo *et al*., 2006). Vacuum packaging of meat products can decrease the rate of oxidation and spoilage when compared to oxygen-permeable packaging (Sahoo & Anjaneyulu, 1997). From microbial safety point of view, inclusion of soybean in meat products could be a support of microbial growth (Pexara *et al*., 2002) because of their available nutrients.

No other published literature is available on the effect of GBF and SHF on lipid stability, microbiological quality and sensory properties of chicken meat nuggets. Therefore, our objective was to investigate the effects of green banana and soybean hull flours (SHF) and vacuum packaging on storage stability and sensory properties of fat chicken nuggets during refrigeration storage.

Materials and methods

Preparation of green banana and soybean hull flours

Raw green bananas (*Musa paradisica* L. subsp. normalis) and soybeans were purchased from local supermarkets at the time of peak production, after that immediately processed in the laboratory. For GBF, raw bananas were boiled at 95 °C for 5 min and peeled off the rind manually. The edible portion was sliced and then dipped into 0.05% sodium metabisulphite (s. d. Fine Chemicals, Mumbai, India) solution for 2 h to prevent enzymatic reaction. Banana slices were washed repeatedly using fresh sodium metabisulphite solution and finally washed with tap water. After drained off excess liquid, they were oven-dried at 60 °C until brittle. SHF was prepared from raw soybean. The raw soybeans were manually peeled off after overnight soaking in tap water. The recovered hulls were boiled in water for 30 min to destroy trypsin inhibitors and haemagglutinins (Kratzer *et al*., 1990). The water content was removed by draining and squeezing, and finally they were dried in a cabinet dryer (Macro Scientific Works, New Delhi, India) at 60 °C for 14 h. Both banana slices and hulls were ground separately in an Inalsa food grinder (Inalsa make, New Delhi, India) to obtain fine particles of flours.

Chicken meat nuggets formulation and processing

The spent male birds of broiler parent stock (IBL-98) of 32-week age were slaughtered in the departmental slaughterhouse as per standard method. The dressed carcases (3.5–4 kg body weight per bird)) were chilled at 4 ± 1 °C for overnight, deboned manually and then divided into small cubes ($5 \times 5 \times 5$ cm^3). The meat cubes were then first minced through a 6-mm grinding plate followed by 4-mm plate in a meat mincer (Kalsi motors, Ludhiana, India). Chicken nuggets were manufactured according to standard formula (only the meat percentages added up to 100% while the percentages of all ingredients are related to meat): 100% lean chicken meat (w/w), 5% chilled water (w/w), 5% refined vegetable oil (w/w), 5% textured soy protein (w/w), 3% refined wheat flour (w/w), 3% condiment (w/w), 3% whole egg liquid (w/w), 1.75% spice mix (w/w), 1.5% sodium chloride (w/w), 0.5% sugar (w/w), 0.2% tetra-sodium pyrophosphate (TSPP, w/w) and 120 mg kg^{-1} sodium nitrite. This original mixture was used as control sample while GBF and SHF were added alone or in combination with other samples with the replacement of lean meat. Three treatments were conducted in which GBF and SHF flour were added alone, respectively, to first (T_1) and second (T_2) treatment at 4% level, while in third (T_3) treatment, 50:50 combination of both flours was used at 4% level. All batches (2 kg per batch) of minced meat samples were mixed separately with the other ingredients in an Inalsa food blender for 1 min. Salt and TSPP were added first, and ice cold water and refined vegetable oil were slowly added at the time of mixing in an Inalsa mixer. Other ingredients were also added simultaneously. After complete mixing, meat batters were taken out and filled up in rectangular shape aluminium moulds ($20 \times 8 \times 5$ cm^3). The filled up moulds were placed in an autoclave and cooked at 6.81 pressures, 121 °C temperature for 20 min. The cooked samples were cooled to room temperature, packed in colourless low density PE bags (150–200 gauges, 24×15 cm^2), sealed and then kept at 4 ± 1 °C before sliced them into nuggets ($5 \times 2 \times 2$ cm^3).

Packaging and storage condition

About 200 g of nuggets samples was vacuum packaged in polyester/cast polypropylene (10/65 μ) laminated

plastic bags (FLEX Industries, Noida, India) and stored at 4 ± 1 °C. Three separate batches of nuggets were prepared for the analysis.

pH and lipid oxidation determination

The pH of cooked nuggets ($n = 6$) was measured on 10 g of sample with a digital (Model: LI 127; Elico make, Hyderabad, India) pH meter equipped with combined glass electrode (Trout *et al*., 1992). Evaluation of 2-thiobarbituric acid-reacting substances (TBARS) was performed ($n = 6$) using TBA test of Witte *et al*. (1970), in which, TCA extract was first filtered through Whatman No. 1 filter paper (s. d. Fine Chemicals) and then 3 mL of this filtrate was mixed with 3 mL of 0.005 M TBA reagent, incubated at 27 ± 2 °C under dark, and finally absorbance (OD) was taken at 532 nm wavelength using UV–VIS spectrophotometer (Elico make). TBARS value was calculated as mg malonaldehyde kg^{-1} of sample by multiplying OD value with K factor 5.2. Both pH and TBARS were determined at 9 days interval in the refrigerated samples. All determinations were performed in duplicate.

Free fatty acids

The method as described by Koniecko (1979) was followed, in which, exactly 5 g of the nuggets was blended with 30 mL of chloroform in the presence of anhydrous sodium sulphate for 2 min. It was then passed through Whatman No. 1 filter paper and filtrate was collected in a 250-mL conical flask. About two or three drops of 0.2% phenolphthalein indicator solution were added to the chloroform extract that was titrated against 0.1 N alcoholic potassium hydroxide to obtain the pink colour end point. The quantity of potassium hydroxide consumed during titration was recorded. Free fatty acid (FFA) content was calculated and expressed as percentage as following –

$$\text{Free fatty acid}(\%) = \frac{0.1 \times \text{mL 0.1 N alcholic KOH} \times 0.282}{\text{Weight of sample (g)}} \times 100$$

Microbiological analysis

Conventional methods recommended by American Public Health Association (1984) were used to enumerate microbiological quality of nugget samples. Samples (10 g) were excised from the nuggets with a sterile scalpel and forceps and then homogenised with 90 mL of sterile 0.1% peptone water in a presterilised mortar for 2 min. Standard plate counts (SPC) were determined on plate count agar (PCA), Coliforms on Violet Red Bile Agar, *Lactobacillus* spp. using Lactobacillus Agar and *Staphylococcal* spp. were counted on Baird-Parker Agar. In all cases, plates were incubated at 37 ± 2 °C for 48 h. The plates for *Lactobacillus* spp. counts (LBC) were incubated in an anaerobic jar and numbers of whitish colonies were counted. Psychrotrophic counts (PTC) were determined on PCA, and the plates were incubated at 4 ± 1 °C for 14 days. Yeast and mould counts were determined on Potato Dextrose Agar, and plates were incubated at 25 ± 2 °C for 7 days. Pour plate methods in duplicate ($n = 6$) were used to analyse the samples. Cultural media were obtained from HiMedia Laboratories Ltd., Mumbai, India.

Sensory evaluation

Samples were evaluated by a seven-member experienced panel of judges from faculty and postgraduate students of College of Veterinary Science, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, India. A Quantitative descriptive analysis was carried out for the attributes of appearance and colour, texture, flavour, juiciness and overall acceptability using eight-point scale, where 8 = extremely desirable and 1 = extremely undesirable (Keeton, 1983). Rectangular pieces approximately $5 \times 2 \times 2$ cm^3 were cut and served to the panel members. Tap water at room temperature was provided to cleanse the palate between samples. The tests were carried out one hour before or two hours after the midday meal. Three sitting ($n = 21$) were conducted on samples warmed in a microwave oven for 20 s.

Statistical analysis

Data were interpreted by two-way analysis of variance (ANOVA) with Duncan's multiple range tests on 'SPSS-12.0' software packages as per the standard methods of Snedecor & Cochran (1994). Statistical significance was expressed at $P < 0.05$.

Results and discussion

pH

The effect of GBF, SHF and combination of both the flours during refrigerated storage of chicken nuggets is illustrated in Table 1. During the initial days of storage, pH was nonsignificantly ($P > 0.05$) higher in SHF treatments followed by control. However, abbreviated decline of pH was observed in all samples until day 9 and then drop significantly ($P < 0.05$) at each storage interval, regardless the treatments. Among the treatments, the results were nonsignificant. Similar findings were reported Kumar *et al*. (2007) in chicken patties incorporated with sorghum and barley flour and pressed rice. In another study, Rubio *et al*. (2007) reported 'salchichon' (a dry fermented sausage) stored in vacuum

Table 1 Effect of green banana and soybean hulls flours on the pH, 2-thiobarbituric-acid reacting substances (TBARS) numbers and free fatty acid (FFA) contents of chicken nuggets

	Storage period (days)					
Treatment	**0**	**9**	**18**	**27**	**36**	**45**
pH						
Control	6.26 ± 0.02^{a}	6.19 ± 0.01^{a}	6.17 ± 0.01^{bA}	6.16 ± 0.01^{bA}	6.11 ± 0.02^{cA}	6.10 ± 0.02^{dA}
T_1	6.24 ± 0.03^{a}	6.20 ± 0.02^{a}	6.11 ± 0.01^{bB}	6.08 ± 0.01^{bcB}	5.99 ± 0.01^{cB}	5.93 ± 0.03^{dC}
T_2	6.28 ± 0.04^{a}	6.24 ± 0.01^{a}	6.15 ± 0.02^{bA}	6.11 ± 0.04^{cB}	6.00 ± 0.01^{dB}	5.98 ± 0.02^{dB}
T_3	6.25 ± 0.03^{a}	6.20 ± 0.01^{a}	6.14 ± 0.04^{bA}	6.09 ± 0.02^{bcB}	5.97 ± 0.01^{cB}	5.94 ± 0.02^{cBC}
TBARS numbers (mg malonaldehyde kg^{-1})						
Control	0.167 ± 0.05^{f}	0.174 ± 0.06^{eA}	0.184 ± 0.01^{dA}	0.222 ± 0.01^{cA}	0.279 ± 0.03^{bA}	0.422 ± 0.05^{aA}
T_1	0.158 ± 0.03^{d}	0.156 ± 0.01^{dB}	0.176 ± 0.01^{cB}	0.178 ± 0.02^{cB}	0.215 ± 0.01^{bC}	0.329 ± 0.01^{aC}
T_2	0.161 ± 0.01^{e}	0.154 ± 0.01^{eB}	0.165 ± 0.01^{dB}	0.190 ± 0.01^{cB}	0.231 ± 0.02^{bB}	0.382 ± 0.01^{aB}
T_3	0.155 ± 0.01^{e}	0.161 ± 0.01^{eB}	0.168 ± 0.03^{dB}	0.182 ± 0.01^{cB}	0.234 ± 0.01^{bB}	0.392 ± 0.02^{aB}
FFA (%)						
Control	0.138 ± 0.01^{bA}	0.133 ± 0.01^{bA}	0.137 ± 0.01^{bA}	0.142 ± 0.01^{abA}	0.163 ± 0.06^{aA}	0.167 ± 0.01^{aA}
T_1	0.111 ± 0.01^{cB}	0.120 ± 0.01^{bB}	0.122 ± 0.01^{bB}	0.132 ± 0.01^{abB}	0.134 ± 0.01^{aC}	0.139 ± 0.01^{aC}
T_2	0.119 ± 0.01^{cB}	0.126 ± 0.01^{bcB}	0.131 ± 0.02^{bA}	0.139 ± 0.01^{bA}	0.144 ± 0.01^{abB}	0.151 ± 0.01^{aB}
T_3	0.116 ± 0.01^{cB}	0.122 ± 0.01^{bcB}	0.130 ± 0.01^{bA}	0.140 ± 0.01^{abA}	0.143 ± 0.02^{abB}	0.152 ± 0.01^{aB}

Control = without added flour, 0%; T_1 = green banana flour (GBF), 4%; T_2 = soybean hull flour (SHF), 4% and T_3 = GBF:SHF (50:50), 4%. Values are mean ± SE (n = 6); values of the same row, followed by same letter (a–f) are not statistically different ($P < 0.05$) as measured by Duncan's multiple range tests. Values are mean ± SE (n = 6); values of the same column, followed by same letter (A–C) are not statistically different ($P < 0.05$) as measured by Duncan's multiple range tests.

packaging a reduction in pH was observed during entire storage periods. The higher initial pH of T_2 samples was because of higher isoelectric pH (6.7–6.8 vs. 5.4–5.7) of soy flour (Sessa, 2004) than GBF (Tribess *et al*., 2009). Control samples showed an abbreviated decline of pH during entire storage period than T_1 or T_2 samples, which could be attributed owing to lower level of fermentable carbohydrates in them. A constant pH up to day 9 and then decreased significantly from 6.25 to 5.93 by the day 45 could be attributed to the activity of lactobacilli and/or dissolution of CO_2 into meat. It is an established fact that a decrease in pH was usually attributed to the metabolic activity of the lactis whereas increase in pH was because of the activity of proteolytic *Pseudomonas* spp. (Laleye *et al*., 1984). Similar findings were also reported in vacuum-packaged frankfurters (Vural *et al*., 2004) and in buffalo meat nuggets (Sahoo & Anjaneyulu, 1997).

Lipid oxidation

Estimation of TBARS numbers, which indicates the oxidative stability of products, showed that control sample was not different from treated nuggets until day 18 (Table 1). The control nuggets had significantly ($P < 0.05$) higher TBARS number which could be attributed to the higher fat level in them (Table 2). Lipid stability of SHF could be because of soy protein fractions (Das *et al*., 2008) while that were for vitamin C and A, glutathione, flavonoid and phenolic compounds in GBF (Suntharalingam & Ravindran, 1993). However, the TBARS numbers in all the nuggets were far below the threshold level of 2 mg malonaldehyde kg^{-1} meat (Witte *et al*., 1970), even up to day 45. This was owing to the fact that vacuum packaging changes the gaseous environment at the meat surface; respire microorganisms at the meat surface or meat itself produces CO_2 and eventually the O_2 concentration within the pack falls below 1% while the CO_2 concentration rises to 20% or more (Eustace, 1981). These resulted in lower TBARS numbers. A positive correlation between microbial growth and TBARS number was reported (Sahoo & Anjaneyulu, 1997).

Free fatty acid contents

FFA content in meat determines the fat status and quality of the product and is expressed as per cent of oleic acid. The control samples had higher ($P < 0.05$) FFA than all the treated samples, and this change was detectable at any storage interval (Table 1). This could be attributed to the release of more FFAs from higher fat containing control products and on subsequent storage because of enzymatic or microbial lipolysis of fat. Among treatments, the FFA content was higher ($P < 0.05$) in T_2 and T_3 samples than T_1. In general, FFA contents increased as the storage period increases, and this result was accorded with the findings of Das *et al*. (2008). However, Bell & Garout (1994) found higher FFA in unspoiled raw beef samples than in

Table 2 Effect of green banana flour (GBF) and soybean hull flour (SHF) on the physicochemical characteristics of chicken nuggets

Parameter	Treatment			
	Control	T_1	T_2	T_3
Emulsion pH	5.92 ± 0.01^{ab}	5.89 ± 0.01^{b}	5.95 ± 0.03^{a}	5.91 ± 0.01^{b}
Product pH	6.21 ± 0.03^{b}	6.18 ± 0.03^{b}	6.25 ± 0.07^{a}	6.21 ± 0.02^{b}
Moisture (%)	64.87 ± 0.50^{b}	67.77 ± 0.60^{a}	65.78 ± 0.72^{b}	66.33 ± 0.60^{ab}
Protein (%)	20.59 ± 0.29^{a}	18.84 ± 0.36^{b}	19.98 ± 0.51^{ab}	19.17 ± 0.23^{ab}
Fat (%)	9.46 ± 0.60^{a}	8.44 ± 0.36^{b}	8.11 ± 0.17^{b}	8.15 ± 0.14^{b}
Crude fibre (%)	0.38 ± 0.07^{d}	2.12 ± 0.10^{c}	2.74 ± 0.18^{a}	2.49 ± 0.13^{b}
Ash (%)	2.40 ± 0.03^{b}	2.56 ± 0.05^{a}	2.69 ± 0.18^{a}	2.53 ± 0.01^{a}

Control = without added flour, 0%; T_1 = GBF, 4%; T_2 = SHF, 4% and T_3 = GBF: SHF (50:50), 4%. Values are mean ± SE (n = 6); values of the same row, followed by same letter (a–d) are not statistically different ($P < 0.05$) as measured by Duncan's multiple range tests.

Table 3 Effect of green banana and soybean hull flours on the microbiological quality* of chicken nuggets

Treatment	Storage period (days)					
	0	9	18	27	36	45
Standard plate count (log cfu g^{-1})						
Control	1.23 ± 0.06^{dA}	1.43 ± 0.09^{cdB}	1.63 ± 0.11^{bB}	2.80 ± 0.11^{bB}	3.17 ± 0.14^{bB}	4.20 ± 0.05^{aB}
T_1	1.17 ± 0.03^{dA}	1.49 ± 0.15^{cB}	1.44 ± 0.12^{cB}	3.03 ± 0.19^{bA}	3.32 ± 0.04^{bB}	4.33 ± 0.03^{aB}
T_2	1.24 ± 0.04^{eA}	1.77 ± 0.09^{dA}	2.15 ± 0.10^{cA}	3.43 ± 0.04^{bA}	4.25 ± 0.04^{bA}	4.80 ± 0.02^{aA}
T_3	1.18 ± 0.03^{dA}	1.82 ± 0.20^{cA}	1.56 ± 0.14^{cdB}	3.11 ± 0.05^{bA}	3.27 ± 0.03^{bB}	4.38 ± 0.02^{aB}
Psychrotrophic count (log cfu g^{-1})						
Control	ND	ND	1.17 ± 0.10^{cA}	1.27 ± 0.04^{bcA}	1.36 ± 0.12^{bA}	1.89 ± 0.01^{aAB}
T_1	ND	ND	1.11 ± 0.13^{cA}	1.13 ± 0.04^{cB}	1.30 ± 0.06^{bA}	1.96 ± 0.05^{aA}
T_2	ND	ND	1.02 ± 0.07^{cB}	1.29 ± 0.03^{bA}	1.37 ± 0.04^{bA}	2.06 ± 0.02^{aA}
T_3	ND	ND	1.04 ± 0.05^{cB}	1.24 ± 0.03^{bA}	1.28 ± 0.02^{bA}	1.85 ± 0.05^{aB}
Lactobacillus spp. count (log cfu g^{-1})						
Control	1.07 ± 0.03^{cA}	1.17 ± 0.07^{cA}	1.63 ± 0.08^{bB}	1.77 ± 0.19^{bB}	2.33 ± 0.10^{aA}	2.37 ± 0.03^{aA}
T_1	1.15 ± 0.01^{dA}	1.18 ± 0.14^{dA}	1.75 ± 0.07$^{c\ B}$	2.18 ± 0.10^{bA}	2.37 ± 0.05^{aA}	2.39 ± 0.03^{aA}
T_2	1.10 ± 0.03^{cA}	1.24 ± 0.13^{cA}	2.08 ± 0.04^{bA}	2.32 ± 0.18^{abAB}	2.43 ± 0.02^{aA}	2.47 ± 0.03^{aA}
T_3	1.17 ± 0.10^{dA}	1.16 ± 0.12^{dA}	1.77 ± 0.24^{cAB}	2.26 ± 0.06^{bA}	2.41 ± 0.02^{aA}	2.43 ± 0.04^{aA}

Control = without added flour, 0%; T_1 = green banana flour (GBF), 4%; T_2 = soybean hull flour (SHF), 4% and T_3 = GBF:SHF (50:50), 4%. Values are mean ± SE (n = 6); values of the same row, followed by same letter (a–e) are not statistically different ($P < 0.05$) as measured by Duncan's multiple range tests. Values are mean ± SE (n = 6); values of the same column, followed by same letter (A–B) are not statistically different ($P < 0.05$) as measured by Duncan's multiple range tests.

*Total coliforms, *Staphylococcus* spp. and Yeast and mould were not detected up to thirtysixth day of storage periods.

samples at onset of spoilage. Modi *et al.* (2007) reported that freshly prepared dehydrated chicken kebab mix had FFA values of 0.99 %, which gradually ($P < 0.05$) increased to 1.74 % during 6 months of storage. In general, FFA level alone did not provide guidance for acceptability of the products, but supports as suitable quality indicator for oxidative changes of fat (Sahoo & Anjaneyulu, 1997).

Microbiological quality

Result in Table 3 shows that during initial days of storage, SPC was significantly ($P < 0.05$) higher in T_2 and T_3 treatments than in T_1 and control samples. The higher SPC in T_2 and T_3 samples might be attributed to more readily utilisable carbohydrates, proteins and metal ions in SHF (Sessa, 2004) by the bacteria (Table 2). In general, SPC increased ($P < 0.05$) in all samples with the increase in storage time, and at the end of the storage, counts were higher in T_2 samples followed by T_3, T_1 and control. T_1 and T_3 samples had lower SPC because of low pH and lack of readily utilisable carbohydrate which is conducive for the growth of bacteria. PTC did not detect up to day 9, but on the day 18, count was significantly ($P < 0.05$) higher in control and T_1 samples than in T_2 and T_3, i.e. PTC was increased over storage time. PTC was absent on days 0 and 9 which might be attributed to the destruction of vegetative cells during

cooking and subsequent metabolic injury that occurred on quick chilling (Leistner, 2000). Coliforms are indicator of postprocessing contamination and were detected occasionally during storage. The presence of this bacterial species in nuggets might be owing to postprocessing contamination during handling. *Staphylococcal* spp. counts and yeast and mould counts (YMC) were also showed similar trend to that of coliforms counts.

Lactic acid bacteria were reported to be the major bacterial group associated with the spoilage of vacuum-packaged cooked meat products (Pexara *et al*., 2002). But in this experiment, LBC did not vary among the treatments up to day 9, and on the day 18, results were significant. Control group showed significantly ($P < 0.05$) lower LBC when compared to treated samples up to day 27, but on further extension of storage time counts were nonsignificant (Table 3). The higher LBC in treated nuggets might be because of more moisture content coupled with more readily utilisable carbohydrate by the lactic acid bacteria. Further, vacuum packaging causes a microbial shift, resulting in the development of *Lactobacillus*-dominated population rather than a high spoilage potential *Pseudomonas* population. Similar results were also reported in vacuum-packaged buffalo meat nuggets (Sahoo & Anjaneyulu, 1997). *Lactobacillus* spp. were shown to spoil vacuum-packaged meat products by causing off-flavour, discolouration, gas formation and slime production (Pexara *et al*., 2002), and in the present study, off-flavour was detected when lactobacillus count reached about 2.4 log cfu g^{-1} at fortyfifth day. So panel members were asked to discontinue to product tasting during the sensory evaluation.

Sensory quality

Quality changes in sensory attributes of chicken meat nuggets during refrigeration storage under vacuum packaging are shown in Table 4. Results indicate that incorporation of GBF and SHF alone in the nuggets did not affect appearance and colour scores among the treatments up to eighteenth day of storage; however, as

Table 4 Effect of green banana and soybean hull flours on the sensory attributes* of chicken nuggets

	Storage period (days)					
Treatment	**0**	**9**	**18**	**27**	**36**	**45**
Appearance and colour						
Control	7.04 ± 0.06^{aA}	6.98 ± 0.05^{aA}	6.85 ± 0.11^{bA}	6.81 ± 0.11^{bA}	6.00 ± 0.17^{cA}	6.02 ± 0.11^{cA}
T_1	7.06 ± 0.07^{aA}	7.02 ± 0.05^{aA}	6.88 ± 0.11^{bA}	6.59 ± 0.12^{cB}	5.69 ± 0.18^{dB}	5.35 ± 0.15^{eC}
T_2	7.02 ± 0.07^{aA}	7.04 ± 0.08^{aA}	6.93 ± 0.10^{aA}	6.64 ± 0.10^{bB}	5.80 ± 0.18^{cB}	5.54 ± 0.15^{dB}
T_3	6.99 ± 0.10^{aA}	6.92 ± 0.09^{aA}	6.78 ± 0.11^{abA}	6.49 ± 0.14^{bB}	5.52 ± 0.19^{cC}	5.43 ± 0.13^{dC}
Flavour						
Control	7.07 ± 0.08^{aA}	7.05 ± 0.07^{aA}	6.88 ± 0.09^{bA}	6.76 ± 0.10^{bA}	5.95 ± 0.18^{cA}	5.92 ± 0.16^{cA}
T_1	7.03 ± 0.08^{aA}	7.04 ± 0.07^{aA}	6.76 ± 0.12^{bA}	6.52 ± 0.12^{cB}	5.57 ± 0.16^{dB}	5.40 ± 0.14^{dB}
T_2	6.94 ± 0.06^{aB}	6.98 ± 0.08^{aA}	6.86 ± 0.10^{abA}	6.48 ± 0.15^{bB}	5.59 ± 0.18^{cB}	5.38 ± 0.14^{dB}
T_3	7.04 ± 0.09^{aA}	6.93 ± 0.08^{aA}	6.69 ± 0.13^{bA}	6.38 ± 0.13^{cB}	5.54 ± 0.19^{dB}	5.26 ± 0.12^{eC}
Texture						
Control	7.09 ± 0.06^{aA}	7.02 ± 0.10^{aA}	6.93 ± 0.13^{abA}	6.69 ± 0.11^{bA}	5.86 ± 0.18^{cA}	5.83 ± 0.15^{dA}
T_1	7.02 ± 0.08^{aA}	7.04 ± 0.08^{aA}	6.97 ± 0.12^{aA}	6.43 ± 0.13^{bB}	5.67 ± 0.19^{cB}	5.33 ± 0.20^{dB}
T_2	6.97 ± 0.07^{aA}	6.95 ± 0.07^{aA}	6.83 ± 0.13^{abA}	6.57 ± 0.15^{bA}	5.62 ± 0.20^{cB}	5.24 ± 0.18^{dB}
T_3	6.94 ± 0.07^{aA}	6.98 ± 0.08^{aA}	6.71 ± 0.13^{abB}	6.52 ± 0.14^{bAB}	5.33 ± 0.20^{cC}	5.14 ± 0.13^{dC}
Juiciness						
Control	7.05 ± 0.06^{aA}	7.00 ± 0.09^{aA}	6.74 ± 0.12^{abB}	6.35 ± 0.14^{bB}	5.88 ± 0.18^{cA}	5.62 ± 0.18^{dA}
T_1	7.08 ± 0.08^{aA}	7.04 ± 0.05^{aA}	6.83 ± 0.14^{abA}	6.68 ± 0.16^{bA}	5.57 ± 0.20^{cB}	5.24 ± 0.16^{dB}
T_2	6.98 ± 0.10^{aA}	7.09 ± 0.07^{aA}	6.78 ± 0.12^{abB}	6.40 ± 0.16^{bB}	5.64 ± 0.19^{cB}	5.21 ± 0.14^{dB}
T_3	6.98 ± 0.09^{aA}	6.98 ± 0.09^{aA}	6.76 ± 0.14^{abB}	6.45 ± 0.13^{bB}	5.47 ± 0.19^{cB}	5.24 ± 0.11^{dB}
Overall acceptability						
Control	7.04 ± 0.05^{aA}	7.01 ± 0.10^{aA}	6.85 ± 0.11^{abA}	6.76 ± 0.14^{bA}	5.88 ± 0.17^{cA}	5.67 ± 0.19^{dA}
T_1	7.04 ± 0.08^{aA}	6.98 ± 0.06^{aA}	6.88 ± 0.11^{abA}	6.45 ± 0.12^{bB}	5.64 ± 0.20^{cB}	5.31 ± 0.20^{dB}
T_2	6.94 ± 0.07^{aA}	6.87 ± 0.05^{aA}	6.86 ± 0.11^{aA}	6.48 ± 0.14^{bB}	5.57 ± 0.21^{cB}	5.33 ± 0.17^{dB}
T_3	7.02 ± 0.09^{aA}	6.94 ± 0.06^{aA}	6.76 ± 0.14^{abA}	6.57 ± 0.13^{bB}	5.52 ± 0.17^{cB}	5.26 ± 0.13^{dB}

*Based on eight-point descriptive scale, where 8 = extremely desirable and 1 = extremely undesirable; Control = without added flour, 0%; T_1 = green banana flour (GBF), 4%; T_2 = soybean hull flour (SHF), 4% and T_3 = GBF:SHF (50:50), 4%.

Values are mean ± SE ($n = 6$); values of the same row, followed by same letter (a–e) are not statistically different ($P < 0.05$) as measured by Duncan's multiple range tests. Values are mean ± SE ($n = 6$); values of the same column, followed by same letter (A–C) are not statistically different ($P < 0.05$) as measured by Duncan's multiple range tests.

the time progresses, all the products exhibited linear but decreasing trends of appearance and colour scores. The decrease in colour scores observed with the advancement of storage days could be attributed to nonenzymatic browning resulted from reaction between lipid oxidation products and amino acids (Che Man *et al.*, 1995). However, even at the end of the storage period, control nuggets had higher ($P < 0.05$) appearance and colour scores and this could be attributed to rapid decrease in moisture content from the treated nuggets which results in concentration of meat pigments (Papadima & Bloukas,1999).

The flavour scores were also unaffected by the addition of GBF and SHF, but control nuggets had significantly higher scores at twentyseventh day than any type of treatments. However, as the storage period progresses, the flavour scores decreased for all the products. The significant reduction in flavour scores with the advancement of storage period could be attributed to the increased lipid oxidation, liberation of FFA and increased microbial load. Similarly, Ho *et al.* (1995) reported that the soy protein concentrate resulted in off-flavour development in reduced-fat pork sausage after 16 weeks of frozen storage.

Like flavour attribute, textural changes of nuggets also followed in similar pattern. However, texture of the nuggets decreased significantly after eighteenth day of storage could be because of increased loss of water in them and subsequent reduction in pH and degradation of muscle fibre protein by the bacterial action (Jay, 1996), which resulted in decrease water-binding capacity. Ho *et al.* (1995) also reported similar findings in sausage patties supplemented with carragreenan and carragreenan–soy products. According to them, tenderness scores declined with the extended period of storage and that were more visible in carragreenan control.

The juiciness scores were unaffected up to ninth day in between the control and treated products, and on day 18, T_1 samples were juicier than other samples. This could be attributed because of the higher water retention capacity by the GBF. But in general, the decrease in juiciness scores observed with the increase in storage period which might be because of inconsistent moisture and fat loss on storage. The control had significantly higher juiciness scores even at the end of the storage period because of comparatively higher fat content in them (Yilmaz, 2005).

The overall acceptability scores were followed the same pattern that observed for other sensory attributes. Although all the treated nugget samples had higher overall acceptability scores, they are comparable with the control only up to day 18, which could be attributed to the higher flavour and textural scores. Treated nuggets did not vary in overall acceptability scores among them at any storage interval even up to end of the storage period. Despite good quality characteristics even on day 45, but owing to development of slight off-flavour and sliminess, it was concluded that nuggets formulated with GBF and SHF had a shelf life of 36 days at refrigerated temperature under vacuum-packaging conditions.

Conclusions

The addition of GBF, SHF and 50:50 combinations of GBF and SHF had some benefits on different physicochemical, microbiological and sensory characteristics of vacuum-packaged chicken nuggets stored at refrigeration temperature. Significantly, lower pH value, TBARS numbers and FFA contents were found in all the treated samples than control. Samples with GBF had lower ($P < 0.05$) FFA contents than other treated products. With respect to microbial quality, SHF-treated samples had significantly higher SPC than control and other treated samples. Total coliforms, *Staphylococcus* spp. and Yeast and mould counts were detected sporadically during entire storage periods. Sensory evaluation results indicated slight off-flavour development and slime formation occurred in all samples on day 45, so they could have shelf life in between 36 and 45 days at 4 ± 1 °C under vacuum-packaging conditions.

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