

## Evaluation of Sodium Alginate as a Fat Replacer on Processing and Shelf-life of Low-fat Ground Pork Patties

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**ABSTRACT :** Low-fat ground pork patties, LFGPP (<10% total fat) formulated with 0.1, 0.2 and 0.3 percent sodium alginate (SA) were processed and compositional, processing and sensory characteristics were compared with control patties containing 20% fat. The moisture content of raw and cooked LFGPP were significantly ( $p < 0.05$ ) higher than control patties because of greater amount of added water in the formulation. The cooking yield, moisture and fat retention also increased linearly in different treatments of LFGPP. The dimensional parameters such as gain in height, decrease in diameter and shrinkage were significantly ( $p < 0.05$ ) lower in LFGPP in comparison to control. Amongst the sensory attributes, flavour showed a declining trend with the increase in concentration of SA in LFGPP. However, low-fat patties with 0.1% SA rated similar to high-fat control. The lipid profile revealed 49.78 and 43.22% decrease in total lipids and cholesterol content respectively, compared to control. The calorie content was reduced significantly ( $p < 0.05$ ) in LFGPP. The texture profile of LFGPP with 0.1% SA was similar to that of high-fat control. The LFGPP remained stable without any appreciable loss of physico-chemical, microbiological and organoleptic quality during refrigerated storage ( $4 \pm 1^\circ\text{C}$ ) for 21 and 35 days in aerobic and vacuum packaging respectively. (**Key Words :** Low-fat Pork Patties, Fat Replacer, Sodium Alginate, Low-cholesterol, Quality of Patties, Storage Stability)

### INTRODUCTION

Texture, flavour and juiciness are the three major components of food acceptability and these are directed by fat content in the formulation especially in comminuted meat products. Fat plays a vital role in sensory properties by binding with heat induced gel, formed of salt extractable proteins in comminuted meat products. With the excessive fat reduction these products become dry, bland and the texture can be hard, rubbery or mealy (Keeton, 1994). However, the dietary fat has been implicated in the development of cardiovascular diseases, hypertension and obesity. Various health organisations have recommended lowering of daily intake of dietary fat to an average of 30% of total calories, consuming less than 300 mg of cholesterol per day and limiting saturated fat to less than 10% of total calories (Matulis et al., 1995). It leads to increase in

consumer demand for low fat meat products.

Various strategies have been employed to minimize the problems related with fat reduction. The active approach is replacement of fat with fat mimetic ingredients which either replace fat or modify interactions of the remaining components (Miller, 1993). Such ingredients include water (Ahmed et al., 1990), starches (Manish Kumar et al., 2004), hydrocolloids (Bloukas et al., 1997; Manish Kumar and Sharma, 2004b), soy protein concentrate and/or isolates (Manish Kumar and Sharma, 2003a), milk proteins (Manish Kumar and Sharma, 2003b), collagen preparates, dietic fibers (Akoh, 1998; Mendoza et al., 2001).

Hydrocolloid gums due to its high binding and gelling property are extensively used as binder in meat products. Alginates are polysaccharides extracted from anionic red or brown seaweed, *Phaeophyceae* and also from giant kelp *Macrocystis pyrifera* (Pomini, 1973). These are linear polymer of D-mannuronic acid and linear polymer of D-mannuronic acid and L-guluronic acid. It is used as sodium or calcium salt in the food system. Various workers used alginates as thickening agent (Hughes et al., 1980), binding agent (Means and Schmidt, 1986) and for enrobing (El-Ebzary et al., 1981) in meat products. Ensor et al. (1989) used calcium lactate-algin combination as binder in

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**Table 1.** Product formulation (g/1,000 g)

Ingredients	Control	Low-fat ground pork patties		
		I	II	III
Lean meat	700	699	698	697
Added fat	150	50	50	50
Added water	50	150	150	150
Refined flour	40	40	40	40
Condiments	30	30	30	30
Spice mix.	15	15	15	15
Salt	15	15	15	15
Sodium nitrite (ppm)	120	120	120	120
Sodium alginate (SA)	-	1.0	2.0	3.0

restructured turkey meat and it improved cooking yield significantly. Berry (1997) used combination of sodium alginate and modified tapioca starch with 7 and 14 per cent added water levels and observed increase in juiciness, tenderness and cooking yield of low-fat (<10%) beef patties. Manish Kumar et al. (2004) also evaluated the combination of sodium alginate and carrageenan as a fat replacer in low-fat pork patties. Park et al. (2000) documented the improvement in cooking yield, textural and sensory properties of low-fat pork patties (10%) with the incorporation of various hydrocolloids (Sodium alginate, Carboxy Methyl cellulose and Xanthan gum).

The present study was undertaken to select the optimum level of sodium alginate as fat replacer in low-fat ground pork patties on the basis of processing, physio-chemical, and sensory characteristics. The lipid profile, texture profile analysis, calorific value and storage life of low-fat and high-fat traditional pork patties were compared.

## MATERIALS AND METHODS

### Formulation and processing of patties:

Market age crossbred (Landrace×Local) hogs (N = 3) weighing 60-70 kg were humanely slaughtered at Divisional Experimental Abattoir of Indian Veterinary Research Institute, Bareilly. Prerigor raw materials were obtained within 1 hr post mortem by fabricating each carcass into boston butt, picnic shoulder, loin and ham. All skin, external fascia, subcutaneous and seam fat and all adhering connective tissues were removed. Hand deboned lean meat and back fat free from adhering skin were stored separately at  $-18\pm 2^\circ\text{C}$  in Low Density Polyethylene (LDPE) packs till use and after partial thawing at  $5^\circ\text{C}$  for 12-15 h for the preparation of ground pork patties. Meat and back fat were cut into small cubes and minced separately through 3 mm plate in Electrolux meat mincer (Model 9512, Electrolux Appliance and Instruments Ltd., Italy).

Sodium alginate was procured from Hi-Media

laboratories Private Limited, Mumbai, India. The spice mixture, condiments and other additives were purchased from local market. The refined wheat flour used as binder has moisture  $18.73\pm 2.11\%$ , carbohydrates  $74.43\pm 0.85\%$ .

The formulation (Table 1) and processing of control and low-fat patties were standardized by preliminary trials. All the ingredients and minced meat constituents were thoroughly mixed by electrically operated meat mixer (Hobart Paddle Mixer, N-50) for 3 min. Immediately after mixing, 75 g of patty mixture was moulded with the help of petridish of 75 mm×15 mm internal size. The moulded patties were cooked in preheated hot air oven at  $190\pm 5^\circ\text{C}$  to an internal end point temperature of  $75\pm 2^\circ\text{C}$  recorded at geometrical centre of each patty using probe thermometer. The patties were turned upside down twice at 5 min interval for better appearance and color and texture. Samples from each batch were analyzed on the same day.

### Cooking determinants:

Cooking yield of patties were determined by measuring the weight of nine patties for each treatment and calculated as ratio of cooked weight to raw weight and expressed in percentage. The percent cooking loss was calculated as the differential weight between individual raw and cooked patties. The moisture and fat retention was calculated according to the following equations:

Fat retention (%)

$$= \frac{\text{Cooked weight} \times \text{per cent fat in cooked patties}}{\text{Raw weight} \times \text{per cent fat in raw patties}} \times 100$$

Moisture retention (%)

$$= \frac{\text{Per cent yield} \times \text{per cent moisture in cooked patties}}{100}$$

The moisture retention value represents the amount of moisture retained in the cooked product per 100 g of raw sample. The diameters and heights of the cooked patties were recorded with the help of vernier caliper at three different positions to obtain mean values. The per cent gain in height and per cent decrease in diameter was calculated in accordance with the methods of Chowdhary et al. (1994). The shrinkage was determined according to equation by El-Magoli et al. (1996):

Shrinkage (%)

$$= \frac{(\text{Raw thickness} - \text{cooked thickness}) - (\text{raw diameter} - \text{cooked diameter})}{\text{Raw thickness} + \text{raw diameter}} \times 100$$

### Physico-chemical analyses

**Composition** : Moisture, fat (ether extractable) and protein content of raw and cooked were determined according to standard AOAC (1995) procedures using hot air oven, soxhlet extraction apparatus and Kjeldahl assembly respectively. All analyses were performed in triplicate.

**pH determination** : Homogenates were prepared by blending 20 g of raw or cooked patties with 80ml of distilled water in Ultra Turrex T25 tissue homogenizer at 7,000-10,000 rpm (4,000-4,500 g) for 1 min. The pH of suspension was measured using digital pH meter (Model CP901 Century Instruments Limited, India).

**Shear force value** : The shear force value of the patties was recorded as per method of Berry and Stiffler (1981) using Warner-Bratzler Shear press (Model: 810310307 GR Elect. Mfg. Co. USA). Ten observations were recorded to obtain the mean value of shear force in kg/cm<sup>2</sup>.

**Calorific value** : Gross energy of sample was determined by Gallenkamp and Ballistic Bomb Calorimeter (Haque and Murarilal, 1999) using Benzoic Acid as a standard and expressed as Kcal/100 g.

Total calorie estimates of raw and cooked ground pork patties were calculated on the basis of 100 g portion using Atwater values for fat (9.0 kcal/g), protein (4.02 kcal/g) and carbohydrates (4.0 kcal/g), the calories contributed by sodium alginate were based on level of incorporation (0, 0.10, 0.20 and 0.30%) and composition. Since analysis of per cent carbohydrates in the meat samples was not performed, the calorie values were estimates and not actual values.

### Sensory evaluation:

An experienced sensory panel consisting of seven scientists and post graduate students evaluate the sensory characteristics of warmed patties at temperature 30-35°C were assessed under incandescent light for their appearance and color, flavor, juiciness, texture and overall acceptability using 8-Point objective Scale (Keeton et al., 1983), where 8 denoted extremely desirable and 1 denoted extremely poor.

### Texture profile analysis (TPA)

Patties samples were cut into 1 cm<sup>2</sup> and subjected to a two cycle compression test performed using a universal Testing Machine (Model-1000, Instron corp., Canton MA). Six samples per treatment were compressed to 50% of their height with 1/2" flat surface plunger attached to 50 N load cell and cross head speed of 50 mm/min. Hardness, chewiness, cohesiveness, springiness and gumminess were calculated from the curve adopting the method described by Brady et al. (1985).

### Lipid profile

The fat content of the samples were extracted adopting the method described by Folch et al. (1957) and Total lipids were determined gravimetrically. The different components of lipids included total phospholipids, total cholesterol, glycolipids and free fatty acids were measured by standard procedures described by Marinetti (1962), Hanel and Dam (1955), Roughan and Batt (1968) and Koniecko (1979) respectively, whereas total glycerides were indirectly calculated by subtracting all these from total lipid values.

### Shelf-life studies

Cooked patties samples were packed in low density polyethylene cling pouches for aerobic storage at refrigeration temperature 4±1°C for 21 days, whereas samples were stored anaerobically/vacuum conditions in multilayered nylon barrier film pouches in natural color at refrigeration temperature 4±1°C for 35 days. The samples were drawn at 7 days interval for assessment of physico-chemical (pH, Thiobarbituric Acid value), microbiological (Total Plate Count, Coliform, Lactic Acid Bacteria counts, Anaerobic count) and sensory attributes.

**Thiobarbituric acid value (TBA)** : TBA value of samples was determined in accordance with TBA distillation method described by Tarladgis et al. (1960).

### Microbiological analysis

A 10 g sample of patties taken in sterilized condition was triturated in sterilized pestle and mortar with 90 ml sterile 0.1% peptone water. Appropriate dilutions of samples were prepared in sterile 0.1% peptone water blank and plated in duplicate on the growth media by pour plate method. The following media and incubation conditions were used.

- Plate Count Agar at 35±2°C for 24 h for total plate count and 4±1°C for 10-14 days for psychrophilic count.
- de Man Rogosa Sharpe (MRS) Agar at 30°C, 48-72 h for lactic acid bacteria.
- Violet Red Bile Agar Media at 35±2°C for 24 h for coli form count.
- Anaerobic agar Media incubated in anaerobic jars at 35±2°C for 48-72 h for Anaerobic Plate Count.

The results were expressed as log<sub>10</sub>cfu/g.

### Statistical analysis

The statistical design of the study was 4 (treatment)×3 (replication) randomized block design. All chemical and physical determinations were conducted in triplicate. There were seven sensory determinations (judges) for each treatment×replication combination. Data were subjected to one way analysis of variance. The storage data were analysed on the basis of 2(treatments) ×4/6 (storage days)×3

**Table 2.** Effect of sodium alginate incorporation on physico-chemical properties of raw and cooked ground pork patties (Mean±SE)\*

Parameters	Control	Level of incorporation of SA (%)		
		0.1	0.2	0.3
<b>Raw patties</b>				
pH	5.95±0.007	5.96±0.006	5.96±0.014	5.97±0.005
Moisture (%)	59.14±0.16 <sup>b</sup>	68.45±0.18 <sup>a</sup>	68.69±0.19 <sup>a</sup>	68.62±0.25 <sup>a</sup>
Fat (%)	19.87±0.11 <sup>a</sup>	9.08±0.05 <sup>b</sup>	8.96±0.15 <sup>b</sup>	9.04±0.17 <sup>b</sup>
Protein (%)	15.46±0.13	15.68±0.20	15.63±0.06	15.61±0.10
Moisture protein ratio	3.83±0.03 <sup>b</sup>	4.37±0.06 <sup>a</sup>	4.39±0.03 <sup>a</sup>	4.39±0.04 <sup>a</sup>
<b>Cooked patties</b>				
pH	6.12±0.006	6.14±0.007	6.13±0.008	6.14±0.008
Moisture (%)	55.46±0.24 <sup>b</sup>	61.28±0.19 <sup>a</sup>	61.59±0.30 <sup>a</sup>	61.82±0.14 <sup>a</sup>
Fat (%)	18.48±0.11 <sup>a</sup>	8.87±0.05 <sup>b</sup>	8.98±0.15 <sup>b</sup>	9.02±0.07 <sup>b</sup>
Protein (%)	18.51±0.08	18.91±0.18	18.88±0.11	18.89±0.27
Moisture protein ratio	3.00±0.03 <sup>b</sup>	3.24±0.05 <sup>a</sup>	3.26±0.04 <sup>a</sup>	3.27±0.03 <sup>a</sup>

\* Mean±SE with different superscripts in a row differ significantly (p&lt;0.05).

N = 6 for each treatment.

**Table 3.** Effect of sodium alginate incorporation on product characteristics of cooked ground pork patties (Mean±SE)\*

Parameters	Control	Level of incorporation of SA (%)		
		0.1	0.2	0.3
Cooking yield (%) <sup>A</sup>	75.21±0.15 <sup>b</sup>	78.34±0.13 <sup>a</sup>	79.24±0.25 <sup>a</sup>	80.08±0.12 <sup>a</sup>
Cooking loss (%) <sup>B</sup>	24.79±0.16 <sup>a</sup>	21.67±0.13 <sup>b</sup>	20.75±0.25 <sup>b</sup>	20.03±0.10 <sup>b</sup>
Decrease in diameter (%)	23.58±0.42 <sup>a</sup>	19.11±0.08 <sup>b</sup>	18.77±0.26 <sup>c</sup>	17.47±0.27 <sup>c</sup>
Gain in height (%)	34.63±0.36 <sup>a</sup>	21.57±0.39 <sup>b</sup>	20.78±0.68 <sup>b</sup>	20.21±0.84 <sup>b</sup>
Shrinkage (%) <sup>C</sup>	13.93±0.35 <sup>a</sup>	12.20±0.19 <sup>b</sup>	12.16±0.24 <sup>b</sup>	11.14±0.26 <sup>c</sup>
Moisture retention (%) <sup>D</sup>	41.87±0.21 <sup>c</sup>	47.97±0.18 <sup>b</sup>	48.84±0.09 <sup>ab</sup>	49.49±0.14 <sup>a</sup>
Fat retention (%) <sup>E</sup>	71.58±0.74 <sup>b</sup>	77.67±0.44 <sup>a</sup>	80.78±0.56 <sup>a</sup>	80.91±0.75 <sup>a</sup>
Shear force value (kg/cm <sup>2</sup> )	0.45±0.02 <sup>a</sup>	0.44±0.02 <sup>a</sup>	0.42±0.01 <sup>ab</sup>	0.40±0.02 <sup>b</sup>

\* Mean±SE with different superscripts in a row differ significantly (p&lt;0.05).

N = 6 for each treatment.

<sup>A</sup> Per cent yield = (raw weight-cooked weight/raw weight)×100.<sup>B</sup> Cooking loss % = 100-per cent yield.<sup>C</sup> Shrinkage % = (Raw thickness- cooked thickness)-(raw diameter- cooked diameter)/(raw thickness- raw diameter).<sup>D</sup> % Moisture retention = % yield×% moisture in cooked patties:100.<sup>E</sup> % Fat retention = (cooked weight×% fat in cooked patties/raw weight×% fat in raw patties)×100.

(replications) with two way analysis of variance. Duncan's Multiple range test and Critical difference were determined at the 5% significance level (Snedecor and Cochran, 1989).

## RESULTS AND DISCUSSIONS

The results of physico-chemical properties of raw and cooked ground pork patties (Table 2) revealed that there is no change in pH of sodium alginate (SA) treated and control patties. This is in agreement with the findings of Esguerra (1994). However, Lin and Keeton (1998) reported the increase in pH of raw low-fat beef patties after addition of alginate at 0.15% and 0.5% carrageenan. The fat content of both raw and cooked low-fat patties were below the limits (<10% total fat) prescribed for low-fat products by Keeton (1994). The fat content of cooked low-fat ground pork patties formulated with SA remained same whereas that of high-fat control patties decreased after cooking because of increased fat loss in the drip (Reitmeir, 1989).

The constant fat content in cooked LFGPP may be attributed to moisture loss on processing and fat binding ability of sodium alginate. The moisture content was inversely proportional to the fat content i.e. higher moisture in lower fat products. This was the result of fat substitution by moisture in low-fat products. The protein content was comparable to the control and LFGPP because of almost the same amount of lean meat being used in each formulation.

Cooking yield was significantly (p<0.05) increased at all levels of SA than control. However, the increased level of SA (Table 3) did not affect the cooking yield. The cooking losses were lower in LFGPP. It could be due to protein-polysaccharide interaction and polymer-ion interaction resulting in thickening and gelling action of alginates (Hughes et al., 1980) which increased the cooking yields. Jeon et al. (2004) also recorded higher cooking yield for low-fat chicken patties with SA. Several workers recorded higher cooking yield with the incorporation of SA in pork patties (Park et al., 2000), low-fat *Kung-Wans* (Hsu

**Table 4.** Effect of sodium alginate incorporation on sensory attributes of low- fat ground pork patties (Mean±SE)\*

Attributes	Control	Level of incorporation of SA (%)		
		0.10	0.20	0.30
Appearance	7.07±0.11	7.03±0.09	7.12±0.06	7.05±0.12
Flavor	7.06±0.08 <sup>a</sup>	6.96±0.09 <sup>a</sup>	6.68±0.12 <sup>b</sup>	6.52±0.09 <sup>b</sup>
Juiciness	7.08±0.09	6.98±0.06	7.02±0.07	7.07±0.09
Texture	6.93±0.08 <sup>a</sup>	7.04±0.10 <sup>ab</sup>	6.92±0.04 <sup>a</sup>	6.68±0.09 <sup>b</sup>
Overall Acceptability	7.05±0.07 <sup>a</sup>	7.07±0.07 <sup>a</sup>	6.73±0.08 <sup>b</sup>	6.59±0.14 <sup>b</sup>

\* Mean±SE with same superscript in a row do not differ significantly ( $p < 0.05$ ).

Means are scores given by sensory panellists on 8-point Objective scale where.

1: extremely poor and 8: extremely desirable.

N = 21 for each treatment.

**Table 5.** Comparison of lipid profile and calorific value of cooked control and low-fat ground pork patties formulated with selected level of sodium alginate

Parameters (mg/g)	Control		Low-fat patties		Mean difference	Per cent decrease
	Mean	SEM	Mean	SEM		
Total lipids	164.47	0.32	82.60	0.66	81.87	49.78
Phospholipids	47.09	0.27	25.67	0.87	21.42	45.48
Glycolipids	0.34	0.02	0.19	0.01	0.15	44.18
Free fatty acids	2.36	0.06	1.34	0.01	1.02	43.22
Cholesterol	2.92	0.04	1.64	0.04	1.28	44.14
Cholesterol (mg/patty)	164.88	0.51	96.39	1.29	68.49	41.54
Total glycerides	111.76	2.67	53.75	0.77	58.01	51.89
Calorific value*	291.68	4.16	228.86	0.78	62.82	21.54
Calorie content** (raw)	258.36	-	161.11	-	97.25	37.64
Calorie content** (Cooked)	256.73	-	172.04	-	102.69	32.98

N = 6 for each treatment.

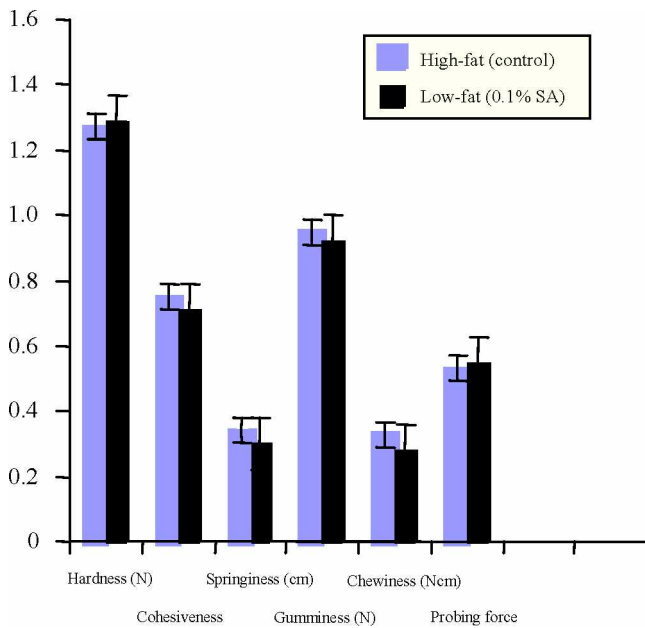
\* Calorific value measured by Gallenkamp and Ballistic Bomb calorimeter (kcal/100 g).

\*\* Estimated kcal based on Atwater values reported on a 100 g per serving basis.

and Chung, 2000), low-fat salami (Zanardi et al., 1998), beef patties (Berry and Liu, 1996) and pork nuggets (Berry, 1994). The dimensional parameters viz. decrease in diameter and gain in height were better maintained in LFGPP. The decrease in diameter was maximum in control and minimum in LFGPP formulated with 0.3% SA whereas, gain in height of patties decreased with increasing level of incorporation amongst the low-fat products. The maximum gain in height was recorded for high-fat control patties. The shrinkage percentage was significantly ( $p < 0.05$ ) lower in LFGPP than control. The increase in moisture and fat retention were directly proportional to the increase in level of incorporation of SA. This may be attributed to formation of heat stable gel in which fat and water were physically entrapped in the alginate matrix resulting in less release water (Onsoyen, 1997) may be attributed to higher cooking temperature of LFGPP because SA had greatest WHC at the higher end point temperature (Lin and Mei, 2000). The increase in water holding capacity was also reported by Berry (1997), Berry (1994) and Abd-Ek Baki et al. (1982). The shear force value was comparable at 0.1 and 0.2% level of incorporation. The softer texture of LFGPP with SA could be attributed to substitution of fat with water which could impart a soft mushy texture to the product (Keeton,

1994; Ahmed et al., 1990). Chin et al. (1998) and Trout et al. (1990) also reported the lower shear force value in low-fat bologna with konjac blend and low-fat restructured chops with sodium alginate respectively.

Mean sensory scores (Table 4) revealed that appearance and juiciness of LFGPP were comparable with a high-fat control at all levels of sodium alginate incorporation. The maximum appearance scores were recorded at 0.2% incorporation level however, it was not statistically significant. Flavour scores showed a declining trend with the increase in level of sodium alginate. The sensory scores of LFGPP for flavour were comparable at 0.1 percent SA and high-fat control. However, the flavour scores decreased significantly ( $p < 0.05$ ) at 0.2 and 0.3 percent levels of SA. Means et al. (1987) also noticed lower flavour scores in restructured beef steaks incorporated with 0.8-1.2 per cent SA. Raharjo et al. (1994) observed undesirable flavour in restructured veal steaks at higher levels of SA incorporation. The sensory panellists rated 0.1% SA level as first with respect to texture. It could probably be due to better texture modification and stabilization actions of SA at this particular level because texture scores decreased significantly ( $p < 0.05$ ) at 0.3% SA incorporation. LFGPP formulated with 0.1% SA had maximum scores for overall



**Figure 1.** Comparative instrumental texture profile of control and formulated with SA low-fat patties.

acceptability, which was comparable to high-fat control patties.

Since cooking yield, moisture retention, flavour, texture and overall acceptability of LFGPP were better or similar to high-fat product at 0.1 per cent level of SA incorporation, it was selected as the optimum level and compared for lipid and texture profile and storage stability to high-fat control.

#### Lipid profile and calorie content

Lipid profile and calorie content of LFGPP formulated with 0.1% SA were compared to high-fat control patties and results are presented in Table 5. The total lipid content of cooked LFGPP (4% added fat) was decreased by 49.78% compared to the control (15% added fat), whereas phospholipids, glycolipids, free fatty acids and total glycerides were reduced by 41-52%. The cholesterol content of each low-fat patty was reduced by 41.54% compared with the high-fat control and the cooked weight of each low-fat patty was higher by almost 3.5% because of better cooking yield. When calorific values were measured directly they were higher than the calorie content calculated by the classical method, when using the 4, 9, 4 kcal/g coefficient for protein, fat and carbohydrate respectively. Trzebska et al. (1979) has also reported higher values of energy when estimated by direct calorimetric measurement and compared with the calculated calorie content. It has been observed that the calorie content of raw control patties was higher than that of the cooked product whereas the calorie content increased in cooked LFGPP when compared to their raw counterpart. This is attributable to more fat loss in the drip from high-fat patties (Reitmeir, 1989; Kregel et

al., 1986) along with high-fat retention in low-fat patties this is because of increased binding ability during cooking caused by SA. Hoelscher et al. (1987) also observed higher fat losses at high added fat levels in ground beef patties and postulated the curvilinear relationship of fat content and calorie content.

#### Instrumental texture profile analysis

The results of Instrumental Texture Profile Analysis are shown in Figure 1. In general low-fat comminuted products are tougher (Barbut and Mittal, 1996; Bloukas et al., 1997) and products with higher added water are tender and soft (Carballo et al., 1995). However in the present study the hardness of LFGPP is comparable to higher fat control. It may be attributed to appropriate amount of added water and the fat replacer, SA (0.1%) in LFGPP. These results are in confirmatory to shear force value. Jeon et al. (2004) also reported comparable hardness value in low-fat chicken patties incorporated with SA to high-fat control (20% added fat). Hsu and Chung (2000); Hwang et al. (1998) and Trout et al. (1990) reported the decrease in hardness value with the incorporation of SA. The springiness, cohesiveness, chewiness were also comparable in LFGPP and high-fat control. However Jeon et al. (2004) reported higher springiness, cohesiveness and chewiness value in low-fat chicken patties. Giese (1992) also documented improvement in chewiness and springiness in low-fat products with the incorporation of hydrocolloids due to formation of gelling and binding nature. The lack of significant variation in these attributes could be due to addition of more water (15% added water) in the formulation. The penetration value (probing force) indicates the resistance offered by the product on being pierced by teeth and depends on gumminess and hardness of the product. As these attributes were similar in LFGPP and high-fat control. Therefore, the probing force values were comparable in both the products.

#### Shelf-life studies

The physico-chemical (pH, TBA), microbiological and sensory properties of LFGPP formulated with 0.1% SA and high-fat control patties during refrigerated ( $4\pm 1^\circ\text{C}$ ) aerobic and vacuum storage are represented in Table 6 and 7. TBA values of control were significantly ( $p < 0.05$ ) higher than LFGPP on day 0 and it increased linearly in both the groups during the storage. The increase was more during aerobic storage due to enhanced lipid oxidation and production of volatile metabolites in the presence of oxygen (Bullock et al., 1994). However, the TBA values remained below the threshold value for sensory perception and no 'off' aroma or flavour was observed. In vacuum packaged product, the TBA value remain almost stable upto day 28, while it was significantly ( $p < 0.05$ ) higher at day 35 in high-fat patties. However it remained stable for LFGPP during the entire

**Table 6.** Effect of refrigerated storage on physico-chemical, microbiological and sensory characteristics of aerobically packaged ground pork patties (Mean±SE)\*

Treatments	Storage period (days)			
	0	7	14	21
<b>Physico-chemical characteristics</b>				
	----- TBA Value (mg malonaldehyde/kg) -----			
Control	0.41±0.018 <sup>d1</sup>	0.52±0.01 <sup>c1</sup>	0.78±0.02 <sup>b1</sup>	0.98±0.01 <sup>a1</sup>
Low-fat patties	0.27±0.007 <sup>d2</sup>	0.37±0.01 <sup>c2</sup>	0.61±0.07 <sup>b2</sup>	0.69±0.01 <sup>a2</sup>
	----- pH -----			
Control	6.12±0.01 <sup>a</sup>	6.22±0.006 <sup>bc</sup>	6.28±0.005 <sup>b</sup>	6.39±0.009 <sup>c</sup>
Low-Fat Patties	6.14±0.007 <sup>a</sup>	6.18±0.005 <sup>ab</sup>	6.26±0.007 <sup>b</sup>	6.32±0.013 <sup>b</sup>
<b>Microbiological characteristics</b>				
	----- Total plate count (log cfu/g) -----			
Control	1.72±0.06 <sup>d</sup>	1.90±0.03 <sup>c1</sup>	2.23±0.05 <sup>b</sup>	2.91±0.04 <sup>a</sup>
Low-fat patties	1.74±0.12 <sup>d1</sup>	2.09±0.06 <sup>c2</sup>	2.27±0.02 <sup>b</sup>	2.70±0.07 <sup>a</sup>
	----- Psychrophilic count (log cfu/g) -----			
Control	ND	ND	1.18±0.03 <sup>b</sup>	1.46±0.09 <sup>a</sup>
Low-fat patties	ND	ND	1.21±0.02 <sup>b</sup>	1.48±0.07 <sup>a</sup>
	----- Coliform count (log cfu/g) -----			
Control	ND	ND	ND	ND
Low-fat patties	ND	ND	ND	ND
<b>Sensory characteristics**</b>				
	----- Appearance -----			
Control	7.09±0.07 <sup>a</sup>	6.97±0.11 <sup>ab</sup>	6.68±0.12 <sup>b</sup>	6.59±0.08 <sup>b</sup>
Low-fat patties	7.00±0.16 <sup>a</sup>	7.02±0.08 <sup>ab</sup>	6.91±0.10 <sup>b</sup>	6.73±0.16 <sup>b</sup>
	----- Flavor -----			
Control	7.07±0.07 <sup>a</sup>	6.88±0.09 <sup>a</sup>	6.67±0.10 <sup>ab</sup>	6.53±0.11 <sup>b</sup>
Low-fat patties	6.98±0.11 <sup>a</sup>	6.93±0.11 <sup>a</sup>	6.81±0.09 <sup>ab</sup>	6.72±0.12 <sup>b</sup>
	----- Juiciness -----			
Control	7.12±0.09 <sup>a</sup>	6.98±0.07 <sup>ab</sup>	6.70±0.10 <sup>bc</sup>	6.59±0.10 <sup>c</sup>
Low-fat patties	7.02±0.08 <sup>a</sup>	6.96±0.06 <sup>a</sup>	6.87±0.09 <sup>ab</sup>	6.73±0.12 <sup>b</sup>
	----- Texture -----			
Control	7.03±0.10 <sup>a</sup>	6.98±0.09 <sup>a</sup>	6.82±0.09 <sup>ab</sup>	6.71±0.08 <sup>b</sup>
Low-fat patties	7.00±0.11 <sup>a</sup>	6.96±0.10 <sup>ab</sup>	6.92±0.09 <sup>ab</sup>	6.86±0.12 <sup>b</sup>
	----- Overall acceptability -----			
Control	7.08±0.09 <sup>a</sup>	6.98±0.08 <sup>ab</sup>	6.78±0.10 <sup>bc</sup>	6.64±0.06 <sup>c</sup>
Low-fat patties	7.04±0.09 <sup>a</sup>	6.98±0.04 <sup>a</sup>	6.91±0.07 <sup>ab</sup>	6.72±0.07 <sup>b</sup>

\* Mean±SE with different superscripts row wise (alphabet) and column wise (numeral) differ significantly ( $p < 0.05$ ).

ND = Not Detected; TBA = Thio-barbituric acid.

N = 21 no. of observations for sensory parameters and N = 6 for other parameters.

\*\* Mean±S.E. with same superscript in a row do not differ significantly ( $p < 0.05$ ).

Means are scores given by sensory panelists on 8-point Hedonic scale where 1: extremely poor and 8: extremely desirable.

storage period. The pH gradually increased during aerobic storage probably because of accumulation of bacterial metabolites and deamination of proteins (Jay, 1996). However, pH declined during vacuum storage because of the production of lactic acid by facultative anaerobic lactic acid bacteria.

The total plate count increased linearly in both the groups during aerobic as well as vacuum storage although the increase was less pronounced with respect to vacuum packaged product. During the initial period of storage TPC was lower in high-fat patties probably because of the presence of high-fat content which acted as a hurdle for the growth of microbes and later because of lipid oxidation, this hurdle was overcome by microbes (Frederick et al., 1994;

Jay, 1996). Coliforms were not detected through out the study because of better hygienic practices and high-temperature treatment during cooking. Anaerobic and lactic acid bacteria were detected only on 28 and 35<sup>th</sup> day of vacuum storage. This could be due to sufficient heat treatment (75°C for 10 min) and the antimicrobial effect of nitrite used in the formulation.

Mean sensory scores (Tables 6 and 7) showed a decreasing trend with increase in storage days. The decrease was more pronounced in aerobic packaged product than vacuum package counterparts. The appearance and flavour scores were reduced significantly ( $p < 0.05$ ) in control product on day 14 and 21 during aerobic storage due to surface dehydration and lipid oxidation. Juiciness scores

**Table 7.** Effect of refrigerated storage on physico-chemical, microbiological and sensory characteristics of vacuum packaged ground pork patties (Mean±SE)\*

Treatments	Storage period (days)					
	0	7	14	21	28	35
<b>Physico-chemical characteristics</b>						
	----- TBA value (mg malonaldehyde/kg) -----					
Control	0.41±0.018 <sup>b1</sup>	0.46±0.007 <sup>b1</sup>	0.47±0.08 <sup>ab1</sup>	0.49±0.012 <sup>ab1</sup>	0.54±0.012 <sup>b1</sup>	0.58±0.004 <sup>b1</sup>
Low-fat patties	0.27±0.007 <sup>2</sup>	0.32±0.04 <sup>2</sup>	0.35±0.007 <sup>d2</sup>	0.37±0.009 <sup>c2</sup>	0.39±0.01 <sup>b2</sup>	0.41±0.009 <sup>a2</sup>
	----- pH -----					
Control	6.12±0.01 <sup>a</sup>	6.12±0.01 <sup>a</sup>	6.08±0.003 <sup>a</sup>	6.01±0.01 <sup>b</sup>	5.96±0.04 <sup>bc</sup>	5.84±0.06 <sup>c</sup>
Low-fat patties	6.12±0.007 <sup>a</sup>	6.13±0.007 <sup>a</sup>	6.06±0.006 <sup>ab</sup>	6.03±0.007 <sup>b</sup>	5.92±0.017 <sup>bc</sup>	5.81±0.02 <sup>c</sup>
<b>Microbiological characteristics</b>						
	----- Total plate count (log cfu/g) -----					
Control	1.72±0.06 <sup>e</sup>	1.81±0.008 <sup>e</sup>	2.06±0.02 <sup>d</sup>	2.21±0.04 <sup>c</sup>	2.70±0.018 <sup>b</sup>	3.26±0.016 <sup>a</sup>
Low-fat patties	1.74±0.12 <sup>f</sup>	1.90±0.15 <sup>e</sup>	2.16±0.015 <sup>d</sup>	2.29±0.004 <sup>c</sup>	2.78±0.013 <sup>b</sup>	3.16±0.04 <sup>a</sup>
	----- Psychrophilic count (log cfu/g) -----					
Control	ND	ND	ND	1.18±0.03 <sup>c</sup>	1.95±0.018 <sup>b</sup>	2.25±0.04 <sup>a</sup>
Low-fat patties	ND	ND	ND	1.21±0.02 <sup>b</sup>	2.02±0.03 <sup>ab</sup>	2.13±0.03 <sup>a</sup>
	----- Anaerobic plate count (log cfu/g) -----					
Control	ND	ND	ND	ND	1.21±0.013 <sup>b</sup>	1.38±0.05 <sup>a</sup>
Low-fat patties	ND	ND	ND	ND	1.18±0.012 <sup>b</sup>	1.33±0.03 <sup>a</sup>
	----- Lactic acid bacteria count (log cfu/g) -----					
Control	ND	ND	ND	ND	1.05±0.024 <sup>b</sup>	1.18±0.007 <sup>a</sup>
Low-fat patties	ND	ND	ND	ND	1.15±0.007 <sup>b</sup>	1.22±0.008 <sup>a</sup>
	----- Coli form count (log cfu/g) -----					
Control	ND	ND	ND	ND	ND	ND
Low-fat patties	ND	ND	ND	ND	ND	ND
<b>Sensory characteristics</b>						
	----- Appearance -----					
Control	7.09±0.07 <sup>a</sup>	7.07±0.08 <sup>ab</sup>	6.95±0.08 <sup>ab</sup>	6.81±0.11 <sup>bc</sup>	6.67±0.10 <sup>c</sup>	6.67±0.12 <sup>c</sup>
Low-fat patties	7.00±0.16 <sup>a</sup>	7.02±0.07 <sup>a</sup>	7.02±0.09 <sup>ab</sup>	6.93±0.09 <sup>bc</sup>	6.79±0.09 <sup>c</sup>	6.81±0.07 <sup>bc</sup>
	----- Flavor -----					
Control	7.07±0.07 <sup>ab</sup>	7.02±0.08 <sup>a</sup>	6.98±0.07 <sup>a</sup>	6.83±0.09 <sup>abc</sup>	6.71±0.07 <sup>bc</sup>	6.60±0.13 <sup>c2</sup>
Low-fat patties	6.98±0.11 <sup>ab</sup>	6.98±0.04 <sup>a</sup>	7.00±0.12 <sup>a</sup>	6.86±0.09 <sup>ab</sup>	6.81±0.06 <sup>ab</sup>	6.76±0.07 <sup>b1</sup>
	----- Juiciness -----					
Control	7.12±0.10 <sup>a</sup>	7.00±0.07 <sup>ab</sup>	6.90±0.09 <sup>abc</sup>	6.86±0.09 <sup>abc</sup>	6.76±0.06 <sup>c</sup>	6.53±0.12 <sup>d</sup>
Low-fat patties	7.02±0.08 <sup>a</sup>	7.00±0.05 <sup>a</sup>	6.98±0.09 <sup>a</sup>	6.88±0.08 <sup>b</sup>	6.71±0.07 <sup>b</sup>	6.65±0.13 <sup>b</sup>
	----- Texture -----					
Control	7.03±0.10 <sup>a</sup>	7.05±0.07 <sup>a</sup>	6.95±0.07 <sup>ab</sup>	6.79±0.08 <sup>bc</sup>	6.81±0.07 <sup>bc</sup>	6.67±0.11 <sup>c</sup>
Low-fat patties	7.00±0.11 <sup>a</sup>	7.00±0.05 <sup>a</sup>	6.93±0.09 <sup>ab</sup>	6.84±0.08 <sup>ab</sup>	6.78±0.06 <sup>b</sup>	6.71±0.10 <sup>b</sup>
	----- Overall acceptability -----					
Control	7.08±0.09 <sup>a</sup>	7.02±0.07 <sup>a</sup>	6.93±0.08 <sup>ab</sup>	6.87±0.08 <sup>ab</sup>	6.71±0.07 <sup>b</sup>	6.59±0.12 <sup>b</sup>
Low-fat patties	7.04±0.09 <sup>a</sup>	7.00±0.08 <sup>a</sup>	7.00±0.05 <sup>a</sup>	6.83±0.09 <sup>ab</sup>	6.79±0.09 <sup>ab</sup>	6.72±0.09 <sup>b</sup>

\* Mean±SE with different superscripts row wise (alphabet) and column wise (numeral) differ significantly ( $p < 0.05$ ).

ND = Not detected; TBA = Thio-barbituric acid N = 21 no. of observations for sensory parameters and N = 6 for other parameters.

\*\* Means are scores given by sensory panelists on 8-point scale where 1: extremely poor and 8: extremely desirable.

were reduced more in aerobic storage due to more moisture loss through air permeable films. However, the sensory panelists rated overall acceptability of LFGPP between good to very good even after 21 days of aerobic and 35 days of vacuum packaged refrigerated storage.

## Conclusions

On the basis of results of cooking determinants, lipid and texture profile and storage studies, this can be concluded that LFGPP prepared with <10% total fat and 0.1% SA had substantially less cholesterol as well as

calories from fat while maintaining sensory and textural attributes similar to high-fat patties with 20% fat. LFGPP can be safely stored at refrigeration temperature ( $4 \pm 1^\circ\text{C}$ ) for 21 days in air permeable films and 35 days in anaerobic conditions without any adverse changes in sensory, microbiological or physico-chemical properties.

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