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Quality characteristics of low-fat beef patties formulated with modified corn starch and water

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Abstract

Low-fat beef patties were produced by replacing different levels of fat with water alone and starch/water combination at different ratios. Quality characteristics of low-fat patties were evaluated. Patties formulated with starch/water had higher moisture content and cooking yield than those formulated with water alone. Incorporation of starch with water in patties formulations improved the instrumental texture characteristics. Low-fat patties had lower visual density and higher saturation than the control. Patties formulated with starch/water had higher sensory ratings for juiciness and tenderness than the control. However, patties formulated with water alone were softer than control. Flavour intensity scores were not affected by replacing fat, except for starch/water combinations at 100% level. Patties formulated with starch/water at all tested ratios were not significantly different in shear force, hardness, springiness, colour and sensory properties. Those formulated with starch/water at a 1:3 ratio were higher in cooking yield and lower in cohesiveness than those at 1:4 and 1:5 ratios.

Keywords: Fat; Beef patties; Modified corn starch; Water; Cooking yield

1. Introducion

The demand for low-fat beef products has greatly increased in recent years due to consumers' concern about high fat diets. High fat intake is associated with increased risk of obesity and some types of cancer, and saturated fat is associated with high blood cholesterol and coronary heart disease (AHA, 1996; USDA & USDHHS, 1995; USDHHS, 1988).

The major problem in acceptability of low-fat processed meat products is the decline in palatability with fat reduction (Ahmed, Miller, Lyon, Vaughters, & Reagan, 1990; Berry, 1997; Mansour & Khalil, 1997). Several studies have shown significantly lower sensory scores for tenderness, juiciness, hardness and flavour in low-fat beef products (Berry, 1994; Berry & Wergin, 1993; Brewer, McKeith & Britt, 1992; Frederick, Miller, Tinney, Bye & Ramsey, 1994; Miller, Andersen, Ramsey & Reagen, 1993; Troutt, Hunt, Johnson, Claus, Kastner & Kropf, 1992). Attempts were made to retain sensory and textural attributes through fat reduction by replacing fat with water (Ahmed et al.; Claus & Hunt, 1991; Frederick et al.; Sutton, Hand & Newkirk, 1995). Although this modification of processing improved tenderness and juiciness, problems of soft texture, purge loss and flavour still remained (Claus, Hunt & Kastner, 1989; Mittal & Barbut, 1994). The inability of meat proteins to bind increased amount of water may explain some excess purge, high yield loss and decreased textural qualities associated with high added water, low-fat products (Claus, Hunt, Kastner & Kroff, 1990; Hensley & Hand, 1995). Because of such effects, water-binding capacity is the critical issue in production. Modified starches have been used to replace fat in processed foods (Akoh, 1998). Starches are known to have water-binding properties (Chin, Keeton, Longecher & Lamkey, 1998; Kim & Lee, 1987; Prabhu & Sebranek, 1997). Therefore, incorporation of starch may be beneficial in low-fat, high-added-water processed meat. Limited research has been published on the effect of a combination of starch and water on the quality characteristics of low-fat patties. The objective of this study was to evaluate the quality characteristics of low-fat beef patties formulated by replacing different levels of fat in patties formulation with water alone and starch/water combinations at different ratios.

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2. Materials and methods

2.1. Formulation of patties

Fresh lean beef and kidney fat were obtained from Shibin El-Kom, Egypt. Lean beef samples were obtained from boneless rounds and trimmed from all subcutaneous and intermuscular fat as well as thick, visible connective tissue. The lean beef and kidney fat sources were separately ground in a Hobart meat grinder (Model# 4046, Hobart Manufacturing Co., Troy, OH). Fat content of the lean and fat portions were determined prior to the manufacture of beef patties. Modified corn starch was provided by the National Starch and Chemical Co., Bridgewater, NJ). The lean beef (4% fat), kidney fat (90% fat), modified corn starch and water were used to formulate the beef patties (Table 1). The control patties were formulated to contain 65% lean beef and 20% kidney fat. Different levels of kidney fat (25, 50, 75 and 100%) were replaced by equal amounts of either water (W) or starch/water (SW) combinations at different ratios (1:3; 1:4 and 1:5). Appropriate amounts of each formulation were mixed by hand, subjected to final grinding (0.4 cm plate) and processed into patties (100 g weight, 1.2 cm thick and 10 cm diameter). Patties were placed on plastic foam meat trays, wrapped with polyethylene film and kept frozen at −18°C until further analysis.

Table 1
Beef patties formulation containing modified corn starch and water

Fat replacement treatment[a]			Lean beef (g)	Kidney fat (g)	Starch (g)	Water (g)
Control			65	20	0	0
25%						
	W[b]		65	15	0	5
	SW[c]	1:5	65	15	0.83	4.17
		1:4	65	15	1.0	4.0
		1:3	65	15	1.25	3.75
50%						
	W		65	10	0	10.0
	SW	1:5	65	10	1.66	8.33
		1:4	65	10	2.0	8.0
		1:3	65	10	2.5	7.5
75%						
	W		65	5	0	15.0
	SW	1:5	65	5	2.5	12.5
		1:4	65	5	3.0	12.0
		1:3	65	5	3.75	11.25
100%						
	W		65	0	0	20.0
	SW	1:5	65	0	3.33	16.66
		1:4	65	0	4.0	16.0
		1:3	65	0	5.0	15.0

[a] All treatments were formulated with 2 g salt, 1.5 g spices mixture, 1 g sugar, 0.2 g tripolyphosphate, 0.3 g ascorbic acid and 10 g water.
[b] Replacing kidney fat with water alone.
[c] Replacing kidney fat with starch/water combinations.

2.2. Cooking procedure

Frozen patties were cooked in a preheated (148°C) electric oven (VEM MLW Medizinische, Greate, Berlin, Germany) which was standardized for temperature. The patties were cooked 6 min, turned over, cooked 6 min, turned again and cooked 4 min. The patties were weighed before and after cooking to determine percentage cooking yield as follows:

$$\%\text{Cooking yeild} = \frac{\text{Weight of cooked patty}}{\text{Weight of uncooked patty}} \times 100$$

2.3. Fat and moisture determination

Fat (ether extraction with Soxhlet apparatus) and moisture (oven drying method) were determined for uncooked and cooked patties using AOAC (1990) procedures. All determinations were conducted in three replicates (two determinations for each replicate). Percentage of fat retention during cooking was calculated as follows

$$\%\text{Fat retention} = \frac{\text{Cooked weight} \times \%\text{Fat in cooked patty}}{\text{Raw weight} \times \%\text{Fat in Raw patties}} \times 100$$

2.4. pH and water holding capacity (WHC)

The pH values of raw patties (aliquots of 10 g/100 ml distilled water) were determined at room temperature (∼25°C) using a digital pH meter (Jenway, Model 3020, Dunmow, Essex, UK). The modified Hamm press technique (Hamm, 1960) was used to measure the water-holding capacity of raw patties. Raw patty (0.3 g) was placed on filter paper (Whatman No. 1, stored overnight in saturated KC1) which was placed between two glass sheets and pressed for 10 min by a 1 kg weight. The area of free water was measured using a compensating polar planimeter and the WHC was calculated.

2.5. Textural measurement

Lee–Kramer shear force values were measured on three patties from each treatment after being cooked and cooled to room temperature using the Ottawa Texture Measuring System (Canners Machinery LTD., ON, Canada) with 900 S mainframe Daytronic Digital Indicator and recorder (Model SP-G 5P, Ricken Denshi Co. Ltd., Japan). The peak force was determined and divided by the weight of each piece to obtain force/gram. Textural profile analysis procedures developed by Bourne (1978) were followed. Slices [3.0×3.0×patty height (cm)] of patties were compressed to 50% of their height for two cycles. Force–time deformation curves were derived with a 5 kg load range, 30 mm/min crosshead speed and 100 mm/min chart speed. Hardness [first compression peak force (kg)], cohesiveness (total energy 2nd compression÷total energy 1st compression ×100) and springiness (base width 2nd compression ÷base width 1st compression×100) were determined.

2.6. Colour evaluation

Colour of cooked patties was determined using a Lovibond Tintometer (The Tintometer LTD., Salisbury, UK). The readings were further converted into CIE units using visual density graphs and the instruction manual supplied with the apparatus.

2.7. Sensory evaluation

Sensory evaluation of cooked patties was performed by eight trained panellists who were graduate students and staff members in the Department of Food Science and Technology Menofiya University. Selection of panellists was based on participant interest, taste and flavour acuity and ability to understand test procedures. Panellists were trained in four 1 h sessions in which they were served patties from a wide variety of treatments to familiarize them with a wide range of sensory characteristics to be evaluated. The panellists were asked to evaluate each sample for tenderness, juiciness, flavour intensity, connective tissue, texture and overall palatability. An eight-point scale was used where 1 = extremely tough, dry, devoid of ground beef flavour, abundant in connective tissue and soft-textured and 8 = extremely tender, juicy, intense in ground beef flavour, absence of connective tissue and firm-textured. Three patties from each treatment were served to each of the panellists during six separate sessions. Two sessions per day were conducted. Each panellist evaluated nine samples per session. Samples were assigned randomly to each panellist and served warm (~40°C). Apple juice and water were provided, so that panellists could cleanse their palates between samples.

2.8. Statistical analysis

An analysis of variance (SAS, 1988) was conducted to analyze the chemical, physical and sensory characteristics of ground beef patties. When a significant main effect was detected, the means were separated with the Student–Newman–Keuls test. The predetermined acceptable level of probability was 5% ($P \leqslant 0.05$) for all comparisons.

3. Results and discussion

3.1. Moisture and fat contents

Moisture and fat percentages of raw and cooked patties, as affected by replacing fat with water alone and starch/water combinations, are presented in Table 2. Moisture and fat contents in raw patties varied according to formulations as expected. Raw moisture values for water replacement treatments were slightly higher than those for starch/water combination treatments at each fat replacement level, reflecting the additional water in these formulations. Following cooking, patties formulated with starch/water combinations had higher ($P \leqslant 0.05$) moisture values than those formulated with water alone. This could be attributed to the water binding ability of the modified starch (Berry & Wergin, 1993; Bullock et al., 1995; Troutt et al., 1992). Generally, heat processing resulted in denaturation of the proteins and hydration of the starch. The water that was not bound tightly by the proteins or the hydrated starch may have been released during cooking. Results clearly showed that cooking increased the fat content on a percentage basis, in all formulations, more than 1% except for the control and 25% fat replacement level treatments which had similar (or lower) percentage of fat to the raw patties. Increasing the fat replacement level up to 100% resulted in significant ($P \leqslant 0.05$) increase in fat retention as result of cooking. At 100% fat replacement level, patties had positive retention (130–138%) of initial fat. However, at 25, 50 and 75% fat replacement levels, patties had negative fat retention

Table 2
Effect of replacing fat with water alone and starch/water conbinations on moisture and fat content of raw and cooked beef patties[a]

Fat replacement treatment			Moisture (%)		Fat (%)		Fat retention (%)
			Raw	Cooked	Raw	Cooked	
Control			63.86[b]	53.03a	21.51e	20.63h	67.20a
25%							
	W		68.25c	56.60b	17.31d	17.58g	74.31cd
	SW	1:5	67.91c	57.29c	17.48d	17.49g	73.06b
		1:4	67.12b	57.52cd	17.54d	17.43g	73.66bc
		1:3	66.51b	58.08d	17.61d	17.40g	74.91d
50%							
	W		71.73e	58.02d	12.33c	14.99f	81.95e
	SW	1:5	70.47d	60.34e	12.49c	13.92e	75.04d
		1:4	70.08d	60.73e	12.53c	13.87e	85.53f
		1:3	69.82d	60.97e	12.60c	13.81e	86.29f
75%							
	W	1:5	74.26g	64.71f	7.47b	9.40d	82.27e
	SW	1:4	73.81fg	65.32g	7.58b	8.34c	88.37g
		1:3	73.34f	65.85gh	7.62b	8.29c	88.35g
			73.03f	66.25h	7.71b	8.23c	88.36g
100%							
	W		77.32i	65.02f	3.41a	6.94b	129.52h
	SW	1:5	76.89i	68.72i	3.53a	5.82a	137.68k
		1:4	76.17h	68.96i	3.65a	5.78a	133.78i
		1:3	75.73h	69.15i	3.71a	5.71a	132.07i
LSD			0.69	0.65	0.76	0.78	0.83

[a] Each value in the table is the mean of three replicates and two determinations were conducted for each replicate.
[b] Means in the same column with different letters are significantly different ($p \leqslant 0.005$).

(73.1–88.4%). These results are in good agreement with those obtained by Hoelscher, Savell, Harris, Cross and Rhee (1987), Berry (1992) and Troutt et al. (1992). Tornberg, Olsson and Persson (1989) concluded that fat was more easily removed from higher fat patties because of a greater probability of encounter and expansion of fat droplets, Also, they further concluded that the dense meat protein matrix of low-fat ground beef prevented fat migration.

3.2. pH, WHC, cooking yield and shear force

pH values of uncooked patties were not significantly different ($P>0.05$) among treatments (Table 3). These results were similar to those obtained by Troutt et al. (1992). The low-fat patties formulated with starch/water combinations had higher ($P\leqslant 0.05$) WHC compared to the control as well as patties formulated with water alone. The WHC was highest in patties formulated with starch/water combinations at 100% fat replacement level and more pronounced at 1:3 starch/water.

Cooking yield was improved ($P\leqslant 0.05$) by replacing fat with starch/water combinations; however, replacing fat with water alone decreased ($P\leqslant 0.05$) the cooking yield. Cooking yields were highest (83.51–85.81%) for patties formulated with starch/water at 100% fat replacement level. Modified starch has been shown to be effective water binders and to improve cooking yield in beef patties (Berry, 1997; Claus & Hunt 1991; Troutt et al., 1992). Data indicated that replacing fat with starch/water combination at a 1:3 ratio gave a higher ($P\leqslant 0.05$) cooking yield than those at 1:4 and 1:5 ratios. Similar improvements in cooking yield as a result of using gels, gums and starches have been reported by Brewer et al. (1992), Berry & Wergin (1993) and Lin and Keeton (1998). Replacing fat in patties with water alone was not effective in improving the cooking yield because most of the water was not bound tightly by the proteins. Also, the high losses in control patties might be attributed to the excessive fat separation and water-release during cooking. These results are consistent with those obtained by Troutt et al. (1992) and Trius, Sebranek, Rus and Carr (1994).

Lee–Kramer shear force (Table 3) was decreased ($P\leqslant 0.05$) by replacing fat with water alone or starch/water combinations. Also, as the fat replacement level increased, the shear force decreased ($P\leqslant 0.05$). It is worth mentioning that replacing fat with water resulted in a marked softness in texture, which was more pronounced at 100% fat replacement level. The shear force values showed that patties formulated with starch/water combinations required more ($P\leqslant 0.05$) force to be sheared than those formulated with water alone within the same fat replacement levels. The effect of starch added to beef patties may be that starch favours formation of stronger heat-induced structures through swelling of starch granules embedded in the protein gel matrix. This would have increased water binding in the protein gel matrix, giving rise to a firmer and more compact structure. Dexter, Sofos and Schmidt (1993) and Schut (1976) noted that starch improved the water binding capacity of meat emulsions. Also, the shear force data indicated that there were no significant differences ($P>0.05$) between starch/water ratios at each fat replacement level.

Table 3
Effect of replacing fat with water alone and starch/water combinations on pH, water-holding capacity, cooking yield and shear force of beef patties[a]

Fat replacement treatment			pH	WHC (%)	Cooking yeild (%)	Shear force (kg/g)
Control			6.22a[b]	62.90a	70.07d	8.27k
25%						
	W	1:5	6.21a	63.21ab	69.23d	5.13f
	SW	1:4	6.20a	65.64c	73.08e	7.47h
		1:3	6.21a	66.13c	74.12e	7.20h
			6.22a	67.82d	75.82f	7.05h
50%						
	W		6.22a	64.08b	67.41c	4.28c
	SW	1:5	6.23a	70.75e	76.33fg	6.60g
		1:4	6.21a	70.88e	77.27g	6.47g
		1:3	6.23a	73.09f	78.73h	6.20g
75%						
	W		6.21a	64.06b	65.38b	3.52b
	SW	1:5	6.22a	75.13g	80.32i	5.07f
		1:4	6.20a	75.93g	81.21i	4.87ef
		1:3	6.22a	77.23h	82.78j	4.73def
100%						
	W		6.22a	64.13b	63.64a	2.18a
	SW	1:5	6.23a	80.74i	83.51jk	4.53cde
		1:4	6.22a	81.39i	84.48k	4.33cd
		1:3	6.21a	83.09j	85.81l	4.20c
LSD			0.04	1.20	1.12	0.43

[a] Each value in the table is the mean of three replicates and two determinations were conducted for each replicate.

[b] Means in the same column with different letters are significantly different ($P\leqslant 0.05$).

3.3. Instrumental texture measurements

Instrumental textural analysis of cooked patties (Table 4) indicated that the peak force (kg) needed for the first compression (hardness) was decreased ($P\leqslant 0.05$) by replacing fat with water alone or starch/water combinations. Also, as the fat replacement level increased, patties were less resistant to compression. The reduction of hardness might be due to the higher moisture content of the low-fat patties compared to the control (Table 2). These data were similar to the results of Ziegler, Rizvi and Acton (1987) who tested several types of dried and non-dried sausages and reported that hardness decreased as moisture increased. Claus, Hunt and Kastner (1989) suggested that at higher levels of

Table 4
Instrumental textural analysis of cooked patties as influenced by replacing fat with water alone and starch/water combinations.[a]

Fat replacement treatment			1st compression (kg)	2nd compression (kg)	Total energy		Springiness	Cohe-siveness
			Hardness		1st compression	2nd compression		
Control			9.2k[b]	7.7k	17.02j	7.08l	79.45h	41.60k
25%								
	W		5.6ef	4.1cdef	10.82gh	3.09efg	74.29ef	28.56d
	SW	1:5	7.3j	5.8j	11.97i	4.32k	77.60g	36.09j
		1:4	6.8ij	5.4ij	11.14h	3.96jk	77.37g	35.55j
		1:3	6.6hi	5.3ij	11.03gh	3.83ij	76.74g	34.72i
50%								
	W		4.5c	3.4b	9.12d	2.23c	71.08d	24.45c
	SW	1:5	6.3ghi	5.0hi	10.80gh	3.56hi	75.00f	32.96h
		1:4	6.2gh	4.9hi	10.56fgh	3.43gh	74.88f	32.88h
		1:3	6.0fg	4.8hi	10.40fg	3.47gh	74.63f	32.12g
75%								
	W							
	SW	1:5	3.7b	2.6a	7.87bc	1.65b	65.15b	20.9b
		1:4	5.8efg	4.5fgh	10.08ef	3.08efg	74.51f	30.56f
		1:3	5.6ef	4.4efgh	9.66de	2.96ef	74.29ef	30.64f
			5.4de	4.2defg	9.33d	2.75de	73.52e	29.47e
100%								
	W		2.8a	2.1a	6.21a	1.21a	62.38a	19.48a
	SW	1:5	4.9cd	3.8bcde	8.31c	2.38cd	67.61c	28.64d
		1:4	4.7c	3.7bcd	7.96bc	2.27c	67.44c	28.52d
		1:3	4.4c	3.5bc	7.41b	2.08c	67.43c	28.06d
LSD			0.50	0.58	0.68	0.39	0.88	0.75

[a] Each value in the table is mean of three replicates and two determinations were conducted for each replicate.
[b] Means in the same column with different letters are significantly different ($p \leqslant 0.05$).

water, the muscle proteins interact with the water rather than form cross-bridges that would increase firmness of beef/pork bologna. Patties formulated with starch/water combinations had higher ($P \leqslant 0.05$) values of hardness than those formulated with water alone at each fat replacement level. These results are in good agreement with those reported by Carballo, Barreto and Jiménez Colmenero (1995) who indicated that the presence of starch had a significant increase in the values of hardness of bologna sausage. Patties formulated with starch/water combinations at all tested ratios (1:3; 1:4 and 1:5) were not significantly different ($P \leqslant 0.05$) in hardness. Data of the second compression had similar pattern to the first compression except that the peak force (kg) needed for the second compression was less than that for the first compression.

Springiness and cohesiveness were decreased ($P \leqslant 0.05$) by replacing fat with water alone or starch/water combinations. Patties formulated with starch/water combinations were more ($P \leqslant 0.05$) cohesive and springy than those formulated with water alone at each fat replacement level. As fat replacement level increased, springiness and cohesiveness decreased. Springiness of low-fat patties was not significantly ($P < 0.05$) affected by the ratio of starch/water combination. However, cohesiveness at 1:3 (starch/water) was lower ($P \leqslant 0.05$) than at 1:4 and 1:5 (starch/water), except at the 100% fat replacement level which showed similar ($P > 0.05$) cohesiveness between starch/water ratios.

3.4. Colour evaluation

Colour attributes of patties (Table 5) are expressed in terms of dominant hue wavelength (colour itself), brightness (lightness or value), saturation (chroma) and visual density ($-\log_{10}$ brightness/100). The low-fat patties formulated with water alone or starch/water combinations had lower ($P \leqslant 0.05$) red colours compared to the control. The reduction of red colour was most pronounced by replacing fat with water, due to the effect of water in diluting the myoglobin concentration. On the other hand, the low-fat patties had higher ($P \leqslant 0.05$) yellow colours compared to control, except at the 25% fat replacement level which were similar to the control. The visual density values of low-fat patties were lower ($P \leqslant 0.05$) than the control. The low values of visual density show a tendency toward a lighter colour compared to the control. The low-fat patties formulated with starch/water combinations at 50, 75 and 100% fat replacement levels were darker than those formulated with water alone, possibly because of a higher degree of nonezymatic browning reaction in meat due to the reactivity of starch with protein.

The brightness of patties followed a trend opposite to that for visual density. The dominant hue wavelength of

Table 5
Colour attributes of cooked patties as influenced by replacing fat with water alone and starch/water combinations[a]

Fat replacement treatment			Red	Yellow	Blue	Visual density	Brightness	Dominant hue wavelength	Saturation
Control			4.1k[b]	1.2a	1.9a	0.22h	59.57a	592e	19.54a
25%									
	W		2.9cd	1.2a	1.9a	0.16cd	68.39f	588ab	20.16b
	SW	1:5	3.6hij	1.2a	1.9a	0.16cd	68.39f	588ab	20.76c
		1:4	3.7ij	1.2a	1.9a	0.16cd	68.39f	588ab	21.39d
		1:3	3.8j	1.3ab	1.9a	0.17de	66.83e	588ab	22.44f
50%									
	W		2.8bc	1.4bc	1.9a	0.15bc	69.98g	588ab	21.83e
	SW	1:5	3.3efg	1.5cd	1.9a	0.17de	66.83e	589bc	24.12h
		1:4	3.4fgh	1.5cd	1.9a	0.17de	66.83e	589bc	24.93i
		1:3	3.5ghi	1.6de	1.9a	0.18ef	65.31d	590cd	25.67k
75%									
	W		2.6ab	1.6de	1.9a	0.14ab	71.83h	587a	23.54g
	SW	1:5	3.1de	1.6de	1.9a	0.18ef	65.31d	590cd	28.32l
		1:4	3.2ef	1.7ef	1.9a	0.18ef	65.31d	591de	29.08m
		1:3	3.2ef	1.7ef	1.9a	0.19fg	63.83c	591de	29.86n
100%									
	W		2.4a	1.8fg	1.9a	0.13a	72.31i	587a	25.33j
	SW	1:5	2.8bc	1.9gh	1.9a	0.19fg	63.83c	591de	30.86o
		1:4	2.8bc	1.9gh	1.9a	0.19fg	63.83c	591de	31.48p
		1:3	2.9cd	2.0h	1.9a	0.20g	62.37b	591de	32.51q
LSD			0.22	0.17	0.14	0.014	0.087	1.61	0.89

[a] Each value in the table is mean of three replicates and two determinations were conducted for each replicate.
[b] Means in the same column with different letters are significantly different ($P \leqslant 0.05$).

cooked patties ranged from 588 to 592 nm and indicated that the general colour of all treatments lay in the area bounded by the red and yellow lines on the spectrum locus of the chromaticity diagram.

The saturation values of low-fat patties increased ($P \leqslant 0.05$) as the fat replacement level increased. The increase in the saturation values indicate more intense colour. Colour attributes (red, yellow, blue, visual density and dominant hue wavelength) were not affected ($P > 0.05$) by starch/water ratios.

3.5. Sensory traits

Sensory traits for cooked patties are shown in Table 6. Tenderness of patties formulated with water was similar ($P > 0.05$) to the control. The starch/water formulations were more ($P \leqslant 0.05$) tender than control except at the 25% fat replacement level which was similar to the control. The improvement in tenderness properties might be due to the considerable swelling of the starch granules during cooking. Berry and Wergin (1993) indicated that the improved tenderness of patties containing potato starch was due to extensively hydrated starch granules which opened the fibrous structure of patties. Tenderness was maximized at 100% fat replacement level. Patties formulated with water or starch/water combinations had higher ($P \leqslant 0.05$) sensory ratings for juiciness than the control. Several investigators (Claus, Hunt & Kastner, 1989; Frederick et al., 1994; Uram, Carpenter & Reagen, 1984) reported that juiciness scores increased primarily as a result of increased added water. In the present study, panellists perceived the treatments containing starch/water combinations to be more juicy than the treatment of water alone. Apparently, the improved water-binding from using the starch could be detected through increased juiciness. Tenderness and juiciness of low-fat patties were not affected ($P > 0.05$) by the starch/water ratios.

Flavour intensity scores were not affected ($P > 0.05$) by replacing fat with water or starch/water combinations except at the 100% fat replacement level with starch/water combinations which showed reduction in flavour intensity scores due to the presence of other flavours identified by the panellists such as sour, meaty and starchy flavours. Also, the low-fat content of this treatment may be insufficient to mask the non-ground beef flavour. Huffman and Egbert (1990) found no differences in beef flavour intensity over a range of 5 to 20% in fat content of patties. Other studies have indicated decreased ground beef flavour using starches, gums and gels (Berry & Wergin, 1993; Brewer et al., 1992; Troutt et al., 1992).

Connective tissue amounts were not affected ($P > 0.05$) by replacing fat in patties. Patties formulated with water were rated softer ($P \leqslant 0.05$) in texture than control. On the other hand, patties formulated with starch/water at 25, 50 and 75% fat replacement level were similar ($P > 0.05$) to the control in firmness, while

Table 6
Sensory properties of patties as influenced by replacing fat with water alone and starch/water combinations[a]

Fat replacement treatment			Tenderness	Juiciness	Flavour intensity	Connective tissue	Texture	Overall
Control			4.8 abc[b]	5.4a	6.2b	6.0a	5.7g	5.4a
25%								
	W		4.4a	5.5a	6.1b	6.1a	4.3c	5.3a
	SW	1:5	5.0bc	5.6ab	6.1b	6.0a	5.6fg	5.6ab
		1:4	5.0bc	5.6ab	6.2b	6.0a	5.5efg	5.6ab
		1:3	5.1cd	5.7abc	6.2b	6.1a	5.5efg	5.6ab
50%								
	W		4.5ab	5.7abc	6.1b	6.0a	4.1e	5.3a
	SW	1:5	5.6de	6.2cd	6.2b	6.1a	5.3defg	5.9bc
		1:4	5.7ef	6.3de	6.2b	6.0a	5.3defg	5.9bc
		1:3	5.8efg	6.4def	6.1b	6.1a	5.3defg	5.9bc
75%								
	W		4.6abc	6.1bcd	6.1b	6.1a	3.6b	5.4a
	SW	1:5	6.2fgh	6.8efg	6.2b	6.0a	5.3defg	6.2c
		1:4	6.3gh	6.9fgh	6.1b	6.0a	5.3defg	6.2c
		1:3	6.4h	7.0ghi	6.2b	6.0a	5.1de	6.2c
100%								
	W		4.7abc	6.8efg	6.1b	6.1a	3.0a	5.5ab
	SW	1:5	7.0i	7.4hi	5.1a	6.1a	5.0d	6.2c
		1:4	7.1i	7.4hi	5.0a	6.0a	5.0d	6.2c
		1:3	7.1i	7.5i	5.0a	6.0a	4.9d	6.2c
LSD			0.50	0.50	0.28	0.33	0.43	0.40

[a] Each value in the table is the mean of three replicates and two determinations were conducted for each replicate.
[b] Means in the same column with different letters are significantly different ($P \leqslant 0.05$).

at 100% fat replacement level the texture was less firm than the control.

The overall acceptability for patties formulated with water was similar ($P > 0.05$) to the control. However, patties formulated with starch/water combination at 50, 75 and 100% fat replacement levels had higher ($P \leqslant 0.05$) overall acceptability scores than the control.

4. Conclusion

From the above results, it could be concluded that some of the physical and sensory characteristic problems associated with low-fat beef patties could be eliminated by replacing fat with a starch/water combination, which proved to be more effective than replacing fat with water alone. In the case of replacing fat with water, sensory panel ratings for tenderness, juiciness and flavour intensity did not differ from the control; however, the cooking yield was lower and the texture was softer than the control. Incorporation of starch with water, resulted in patties that were higher in cooking yield than the control and provided improvements in texture characteristics. Also, starch/water combinations improved the sensory properties of patties at all fat replacement levels except flavour intensity and texture at the 100% level. Therefore, the low-fat patties could be produced by replacing fat with starch/water combination up to 75% fat replacement level.

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