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EFFECT OF CARBOHYDRATE-BASED FAT REPLACERS ON THE QUALITY CHARACTERISTICS OF LOW-FAT BEEFBURGERS

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ABSTRACT

Low-fat beefburgers were prepared by replacing different levels of fat with the carbohydrate-based fat replacers (modified cornstarch, tapioca starch and tapioca dextrin). Quality characteristics of low-fat beefburgers were evaluated to select the best fat replacer type and level to be combined with carboxy methylcellulose (CMC) or calcium alginate (CA). Beefburgers formulated with modified cornstarch or tapioca starch had higher cooking yield, water holding capacity (WHC) and sensory properties than beefburgers formulated with tapioca dextrin. The best level of modified cornstarch or tapioca starch was 75% as indicated by the cooking yield and sensory properties. Addition of CMC or CA to the modified cornstarch or tapioca starch increased the cooking yield and WHC and reduced the shear force of the low-fat beefburgers compared to the 20% fat control and 75% fat replacement level controls prepared by modified cornstarch or tapioca starch alone. Addition of CMC or CA (at expense of fat) at 0.1% level showed similar ($P > 0.05$) sensory properties as in the 75% fat replacement level controls. However, their addition at 0.2% level showed similar ($P > 0.05$) sensory properties as in the 20% fat control. The texture profile analysis of the low-fat beefburgers formulated with modified cornstarch or tapioca starch alone and their combinations with CMC or CA showed a decrease in hardness and an increase in springiness and cohesiveness.

Key words: *beefburger, cooking yield, fat, replacers fat, sensory properties.*

1. INTRODUCTION

Fats are important sources of certain nutrients and food energy and also contribute to food texture, flavor and satiety after eating (Akoh, 1998 and Miller *et al.,* 1993). High fat intake is associated with increased risk of obesity (AHA, 1996), some types of cancer and coronary heart disease (USDA and USDHHS, 1995). During the past 10 to 15 years, the American Heart Association and other health organizations have encouraged reduction of fat from food to less than 30% of calories for most people (AHA, 1996 and USDHHS, 1988).

The major problem in acceptability of low-fat processed meat products is the decline of palatability with fat reduction (Troutt *et al.,* 1992 and Claus *et al.,* 1990). Several trials have been made to maintain acceptable sensory and textural attributes through fat reduction by replacing fat with water (Ahmed *et al.,* 1990), phosphate and water (Frederick *et al.,* 1994), dietary fiber (García *et al.,* 2002, Mansour and Khalil, 1999 and Claus and Hunt, 1991), (Mubarak, 2001 and Lin and Keeton, 1998), modified starches (Beggs *et al.,* 1997 and Berry, 1997), texture modifying ingredients (Troutt *et al.,* 1992) and inulin (Mendoza *et al.,* 2001).

Researches conducted for the combination of hydrocolloids in low-fat ground meat products are limited. Conceivably synergistic effects may occur because of their unique properties. Bullock *et al.,* (1995) reported higher overall acceptability scores for low-fat patties manufactured with xanthan and locust bean gums compared to patties formulated with carrageenan only. Beggs *et al.,* (1997) reported improvements in sensory and physical characteristics of reduced-fat turkey frankfurters prepared with combination of modified cornstarch and water. In the present study, fat in beefburgers was replaced with different types of carbohydrate-based fat replacers (modified cornstarch, tapioca starch and tapioca dextrin). The best treatments (based on cooking yield and sensory properties) were also selected to be combined with different levels of carboxy methylcellulose (CMC) or calcium alginate (CA). The objective of this study was to evaluate the chemical, physical and sensory characteristics of low-fat beefburgers formulated by replacing different levels of fat in beefburgers formulation with fat replacers alone and with fat replacers and CMC or CA combination at different levels.

2. MATERIALS AND METHODS

2.1. Materials

2.1.1. Fresh lean beef and fat were obtained from the slaughterhouse in 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.

2.1.2. Modified cornstarch, tapioca starch and tapioca dextrin were provided by the National Starch and Chemical Co., Bridgewater, NJ, USA. Calcium alginate was obtained from Aldrich Chemical Company, Milwaukee, WI, USA. Carboxy methylcellulose, high viscosity was provided by Sigma Chemical Company, St-Louis, MO, USA.

2.1.3. Salt, sugar and spice mixture were obtained from local market in Shibin El-Kom, Egypt.

2.2. Methods

2.2.1. Formulation of beefburgers

The lean beef and fat sources were separately ground in a Hobart meat grinder (Model No. 4046, Hobart Manufacturing Co., Troy, OH, USA). Fat content of the lean and fat portions were determined prior to the manufacture of beefburgers. The lean beef (4% fat), fat (90% fat), modified cornstarch, tapioca starch, tapioca dextrin and water were used to formulate the beefburgers (Table 1). The control beefburgers were formulated to contain 65% lean beef and 20% fat. Different levels of fat (25, 50, 75 and 100%) were replaced by equal amounts of the 30% aqueous solution of each fat replacer. The best two treatments (based on cooking yield and sensory properties) were chosen to be combined with different levels (0.1, 0.2

and 0.3%) of CMC and CA. Carboxy *methylcellulose or calcium* alginate was replaced by equal amounts of fat. Appropriate amounts of each formulation were mixed by hand, subjected to final grinding (0.4 cm plate) and processed into beefburgers (100g weight, 1.2cm thick and 10cm diameter). Beefburgers were placed on foam meat trays, wrapped with polyethylene film [thickness 25 μm, oxygen transmission rate 2500 $cm^3/(m^2$ 24 h atm)] and kept frozen at −18°C for 7 days.

Table (1): Beefburger formulation containing modified cornstarch, tapioca starch and tapioca dextrin.

Fat replacement treatment[1]	Lean beef (g)	Fat (g)	Modified cornstarch[2] (g)	Tapioca (g) starch[2]	Tapioca dextrin[2] (g)
Control	65	20	-	-	-
25%					
Modified cornstarch	65	15	5	-	-
Tapioca starch	65	15	-	5	-
Tapioca dextrin	65	15	-	-	5
50%					
Modified cornstarch	65	10	10	-	-
Tapioca starch	65	10	-	10	-
Tapioca dextrin	65	10	-	-	10
75%					
Modified cornstarch	65	5	15	-	-
Tapioca starch	65	5	-	15	-
Tapioca dextrin	65	5	-	-	15
100%					
Modified cornstarch	65	0	20	-	-
Tapioca starch	65	0	-	20	-
Tapioca dextrin	65	0	-	-	20

[1]All treatments were formulated with 2g salt, 1.5g spice mixture, 1g sugar, 0.2g tripolyphosphate, 0.3g ascorbic acid and 10g water.

[2]30% aqueous solution was prepared for each fat replacer.

2.2.2. Cooking procedure

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

$$\%\text{Cooking yield} = \frac{\text{Weight of cooked beefburger}}{\text{Weight of uncooked beefburger}} \times 100$$

2.2.3. Fat and moisture determination

Fat (ether extraction with Soxhlet apparatus) and moisture (oven drying method) were determined for uncooked and cooked beefburgers using AOAC (1990) procedures. All determinations were conducted in three replicates (two determinations for each replicate). Percentage of fat retention during cooking was calculated according to Khalil (2000) as follows:

$$\%\text{Fat retention} = \frac{\text{Cooked weight} \times \%\text{fat in cooked beefburger}}{\text{Raw weight} \times \%\text{fat in raw beefburger}} \times 100$$

2.2.4. pH and water holding capacity (WHC)

The pH values of raw beefburgers (aliquots of 10g/100ml distilled water) were determined at ~25°C according to Khalil (2000) 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 (WHC) of raw beefburgers. Raw patty (0.3g) was placed on filter paper (Whatman No. 1, stored overnight in saturated KCl), which was placed between two glass sheets and pressed for 10 min by a 1kg weight. The area of free water was measured using a polar planimeter and the WHC was calculated.

2.2.5. Textural profile analysis

Lee-Kramer shear force values were measured on three beefburgers from each treatment after being cooked and cooled to room temperature (~25°C) using the Ottawa Texture Measuring System (Canners Machinery LTD, ON, Canada) with 900S 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 × beefburger height (cm)] of beefburgers were compressed to 50% of their height for two cycles. Force-time deformation curves were derived with a 5kg load range, 30 mm/min crosshead speed and 100 mm/min chart speed. Hardness, cohesiveness and springiness were calculated as follows:

Hardness = First compression peak force (kg)

$$\text{Cohesiveness} = \frac{\text{Total energy of 2nd compression}}{\text{Total energy of 1st compression}} \times 100$$

$$\text{Springiness} = \frac{\text{Base width, } 2^{nd} \text{ compression}}{\text{Base width, } 1^{st} \text{ compression}} \times 100$$

2.2.6. Sensory evaluation

Eight-trained panellists who were graduate student and staff members in the Department of Food Science and Technology Menofiya University performed sensory properties of cooked beefburgers. Selection of panellists was based on participant interest, taste and flavor acuity and ability to understand test procedures. An eight-point scale was used where 1 = extremely tough, dry, devoid of ground beef flavour and abundant in connective tissue and 8 = extremely tender, juicy, intense in ground beef flavour and absence of connective tissue. Samples were assigned randomly to each panelist and served warm (~40°C).

2.2.7. Statistical analysis

An analysis of variance (SAS, 1995) was conducted to analyze the chemical, physical and sensory characteristics of beefburgers. 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% ($P \leq 0.05$) for all comparisons.

3. RESULTS AND DISCUSSION

Table (2) shows the effect of replacing fat with modified cornstarch, tapioca starch and tapioca dextrin on moisture and fat contents of raw and cooked beefburgers. Moisture and fat contents in raw beefburgers varied according to formulations as expected. Moisture content of raw low-fat beefburgers formulated with fat replacers was significantly ($P \leq 0.05$) higher than the control. As fat replacement level increased in raw beefburgers moisture contents increased ($P \leq 0.05$). This could be attributed to the water binding ability of the fat replacers (Khalil, 2000, Bullock *et al.*, 1995 and Berry and Wergin, 1993). Moisture content was highly reduced by cooking. This reduction is attributed to the releasing of water, which was not bound tightly by proteins or hydrated starch during cooking (Khalil, 2000). Cooked beefburgers formulated with fat replacers had higher ($P \leq 0.05$) moisture contents than control. Beefburgers formulated with modified cornstarch and tapioca starch at any fat replacement level lost less ($P \leq 0.05$) moisture during cooking than beefburgers formulated with tapioca dextrin. This might be due to the difference in water holding capacity between starch and dextrin especially during cooking. Troutt *et al.*, (1992) reported that patties with polydextrose, potato starch and pea fiber lost as little as 3.3% moisture during cooking compared to control (6.7%).

Control beefburgers had higher fat content than those formulated with fat replacers. Cooking increased the fat content on a percentage basis, in all formulations, more than 1% except for the control and at 25% fat replacement level treatments, which had similar (or lower) percentage of fat to the raw beefburgers. Tornberg *et al.*, (1989) concluded that fat was more easily removed from higher fat patties because of a greater probability of encounter and expansion of fat droplets. They further concluded that the dense meat protein matrix of low-fat ground beef prevented fat migration. Increasing the fat replacement resulted in a significant ($P \leq 0.05$) increase in fat retention as a result of cooking. These results are in good agreement with those obtained by Hoelscher *et al.*, (1997). Khalil (2000) reported that at 100% fat replacement level prepared by modified cornstarch, patties had positive retention (130-138%) of initial fat;

however at 25, 50 and 75% fat replacement levels, patties had negative fat retention (73.1-88.4%).

Table (2): Effect of replacing fat content with different levels of modified cornstarch, tapioca starch and tapioca dextrin on moisture and fat contents of raw and cooked beefburgers.

Fat replacement treatment	Moisture (%)		Fat (%)		Fat retention
	Raw	Cooked	Raw	Cooked	(%)
Control	65.22[a]	54.64[a]	22.36[e]	20.92[e]	65.84[a]
25%					
Modified cornstarch	66.81[c]	56.72[c]	18.27[d]	18.32[d]	68.72[b]
Tapioca starch	66.72[c]	56.88[c]	18.32[d]	18.38[d]	68.66[b]
Tapioca dextrin	65.90[b]	55.65[b]	18.41[d]	18.30[d]	69.13[b]
50%					
Modified cornstarch	67.63[d]	58.91[e]	13.53[c]	14.75[c]	74.28[c]
Tapioca starch	67.52[d]	58.63[e]	13.50[c]	14.62[c]	74.32[c]
Tapioca dextrin	66.61[c]	57.81[d]	13.40[c]	14.69[c]	74.51[c]
75%					
Modified cornstarch	68.81[e]	61.68[g]	8.66[b]	10.42[b]	79.88[d]
Tapioca starch	68.61[e]	61.42[g]	8.55[b]	10.52[b]	80.49[d]
Tapioca dextrin	67.82[d]	60.05[f]	8.60[b]	10.60[b]	80.40[d]
100%					
Modified cornstarch	71.73[g]	63.61[i]	4.42[a]	6.92[a]	90.64[e]
Tapioca starch	71.68[g]	63.73[i]	4.46[a]	6.82[a]	90.70[e]
Tapioca dextrin	70.42[f]	62.08[h]	4.40[a]	6.86[a]	91.10[e]
LSD	0.63	0.81	0.54	0.65	0.89

[a-i]Means in the same column with different letters are significantly different ($P \leq 0.05$).

The pH values of low-fat beefburgers were not significantly affected ($P > 0.05$) by the level and type of fat replacers (Table 3).

These results are in good agreement with those obtained by Mubarak (2001), Khalil (2000) and Lin and Keeton (1998). The cooking yield was significantly ($P \leq 0.05$) increased by replacing fat with fat replacers. As the fat replacement level increased, the cooking yield increased ($P \leq 0.05$). Starches have been shown to be effective water binders and to improve cooking yield in beef patties (Khalil, 2000 and Berry, 1997). All low-fat beefburgers formulated with fat replacers had higher ($P \leq 0.05$) WHC than control.

Table (3): Effect of replacing fat content with different levels of modified cornstarch, tapioca starch and tapioca dextrin on pH, cooking yield, water holding capacity and shear force of beefburgers.

Fat replacement treatment	pH	Cooking yield (%)	WHC[1] (%)	Shear force (kg/g)
Control	6.76^{a}	67.23^{a}	62.19^{a}	8.46^{i}
25%				
Modified cornstarch	6.76^{a}	71.78^{c}	65.95^{c}	7.62^{h}
Tapioca starch	6.74^{a}	71.82^{c}	65.82^{c}	7.55^{h}
Tapioca dextrin	6.74^{a}	70.11^{b}	64.92^{b}	7.31^{g}
50%				
Modified cornstarch	6.75^{a}	76.92^{e}	71.92^{e}	6.46^{f}
Tapioca starch	6.75^{a}	76.80^{e}	71.82^{e}	6.38^{f}
Tapioca dextrin	6.74^{a}	74.21^{d}	70.20^{d}	6.09^{e}
75%				
Modified cornstarch	6.74^{a}	83.82^{g}	75.89^{g}	5.25^{d}
Tapioca starch	6.75^{a}	83.76^{g}	75.71^{g}	5.19^{d}
Tapioca dextrin	6.76^{a}	80.21^{f}	74.32^{f}	4.92^{c}
100%				
Modified cornstarch	6.74^{a}	85.59^{i}	81.94^{i}	3.96^{b}
Tapioca starch	6.76^{a}	85.98^{i}	81.81^{i}	3.92^{b}
Tapioca dextrin	6.74^{a}	82.35^{h}	80.21^{h}	3.70^{a}
LSD	0.12	1.11	0.92	0.18

[a-i]Means in the same column with different letters are significantly different ($P \leq 0.05$).
[1]Water holding capacity

Lee-Kramer shear force was significantly ($P \leq 0.05$) decreased by replacing fat with fat replacers. As the fat replacement level increased, the shear force decreased ($P \leq 0.05$). This could be attributed to the softness in texture, which was more pronounced at 100% replacement level as a result of improving the water binding capacity. Data indicated that low-fat beefburgers formulated with modified cornstarch and tapioca starch at any fat replacement level had higher ($P \leq 0.05$) cooking yield, WHC and shear force than those formulated with tapioca dextrin. The moisture content data of these products (Table 2) supported these results.

Table (4): Effect of replacing fat content with different levels of modified cornstarch, tapioca starch and tapioca dextrin on sensory properties of beefburgers.

Fat replacement treatment	Tenderness	Juiciness	Flavour intensity	Connective tissue	Overall acceptability
Control	4.9^{a}	5.1^{a}	6.0^{b}	5.7^{a}	5.4^{a}
25%					
Modified cornstarch	5.5^{c}	5.9^{c}	6.0^{b}	5.9^{a}	6.0^{cd}
Tapioca starch	5.5^{c}	6.0^{c}	6.1^{b}	5.9^{a}	6.0^{cd}
Tapioca dextrin	5.2^{b}	5.5^{b}	6.0^{b}	5.9^{a}	5.7^{b}
50%					
Modified cornstarch	6.1^{e}	6.4^{d}	6.0^{b}	5.9^{a}	6.3^{ef}
Tapioca starch	6.2^{e}	6.4^{d}	6.0^{b}	5.9^{a}	6.3^{ef}
Tapioca dextrin	5.8^{d}	6.0^{c}	6.1^{b}	5.9^{a}	6.0^{cd}
75%					
Modified cornstarch	6.9^{g}	6.9^{e}	6.1^{b}	5.9^{a}	6.8^{g}
Tapioca starch	6.8^{g}	6.8^{e}	6.0^{b}	5.9^{a}	6.8^{g}
Tapioca dextrin	6.5^{f}	6.4^{d}	6.0^{b}	5.9^{a}	6.5^{f}
100%					
Modified cornstarch	7.3^{h}	7.4^{f}	5.5^{a}	5.7^{a}	6.2^{de}
Tapioca starch	7.2^{h}	7.4^{f}	5.5^{a}	5.7^{a}	6.2^{de}
Tapioca dextrin	6.8^{g}	7.0^{e}	5.5^{a}	5.7^{a}	5.9^{bc}
LSD	0.2	0.3	0.2	0.3	0.2

[a-h]Means in the same column with different letters are significantly different ($P \leq 0.05$).

Sensory properties for beefburgers are presented in Table (4). Beefburgers formulated with fat replacers were more ($P \leq 0.05$) tender than the control. The improvements in tenderness of low-fat beefburgers is attributed to the swelling of starch granules in the composition of the fat replacers 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. Similar results were reported by Khalil (2000) and Beggs *et al.*, (1997).

Low fat beefburgers had higher ($P \leq 0.05$) sensory ratings for juiciness than the control. The improved water holding capacity (Table 3) from using modified cornstarch, tapioca starch and tapioca dextrin could be detected through increased juiciness. Several studies have indicated increased ground beef juiciness from using starches (Crehan *et al.*, 2000, Khalil, 2000 and Lin and Keeton, 1998).

Flavour intensity in beefburgers was not affected ($P \leq 0.05$) by replacing fat except at 100% fat replacement level for all fat replacers which showed reduction ($P \leq 0.05$) in flavours intensity scores due to the presence of other flavour identified by the panellists such as sour, meaty and starchy flavours. Similar results were obtained by Khalil, (2000). The effects of using fat replacers on the intensity of beef flavour were inconsistent with Lin and Keeton (1998) who reported that low fat ground beef containing carrageenan had improved beef flavour intensity and no increase in off-flavours compared to the control. Other studies have indicated decreased ground beef flavour from using starches and gums (Brewer *et al.*, 1992 and Troutt *et al.*, 1992). Connective tissue amounts were not significantly ($P > 0.05$) affected by replacing fat in beefburgers with fat replacers. These results are consistent with those reported by Khalil (2000).

The overall acceptability for beefburgers formulated with fat replacers was higher ($P \leq 0.05$) than the control. Beefburgers formulated with fat replacers at 75% fat replacement level had higher ($P \leq 0.05$) scores for overall acceptability than those formulated at 100% fat replacement level. Sensory properties data indicated that low-fat beefburgers formulated with modified cornstarch and tapioca starch at any fat replacement level had higher ($P \leq 0.05$) scores for tenderness, juiciness and overall acceptability than those formulated with tapioca dextrin. Beefburgers formulated with modified cornstarch or tapioca starch at 75% fat replacement level were selected (based on cooking yield and sensory properties) to be combined with carboxy methylcellulose (CMC) or calcium alginate (CA).

Table (5): Effect of different levels of carboxy methylcellulose (CMC) and calcium alginate (CA) on moisture and fat contents of raw and cooked low-fat beefburgers.

Fat replacement treatment	Moisture (%)		Fat (%)		Fat retention
	Raw	Cooked	Raw	Cooked	(%)
Control (20% fat)	65.22^{a}	54.64^{a}	22.36^{b}	20.92^{f}	65.84^{a}
Control (75% cornstarch)	68.56^{b}	60.64^{b}	8.64^{a}	10.90^{e}	79.94^{b}
Control (75% tapioca starch)	68.83^{b}	60.51^{b}	8.52^{a}	11.08^{e}	80.46^{b}
75% Modified cornstarch					
with 0.1% CMC	71.64^{cd}	62.84^{de}	8.54^{a}	10.10^{cd}	79.85^{b}
with 0.2% CMC	73.82^{fg}	64.92^{fg}	8.52^{a}	9.74^{abc}	79.76^{b}
with 0.3% CMC	76.52^{h}	66.76^{h}	8.56^{a}	9.28^{a}	79.85^{b}
with 0.1% CA	71.24^{c}	61.72^{c}	8.51^{a}	10.22^{cd}	79.78^{b}
with 0.2% CA	72.93^{ef}	62.86^{de}	8.57^{a}	9.92^{bc}	79.81^{b}
with 0.3% CA	74.51^{g}	64.54^{f}	8.58^{a}	9.76^{abc}	79.72^{b}
75% Tapioca starch					
with 0.1% CMC	70.92^{c}	62.38^{d}	8.46^{a}	10.12^{cd}	80.42^{b}
with 0.2% CMC	73.30^{ef}	63.25^{e}	8.48^{a}	9.88^{bc}	80.40^{b}
with 0.3% CMC	75.65^{h}	65.34^{g}	8.46^{a}	9.42^{ab}	80.36^{b}
with 0.1% CA	71.10^{c}	61.40^{c}	8.49^{a}	10.24^{cd}	80.38^{b}
with 0.2% CA	72.34^{de}	62.56^{d}	8.47^{a}	9.86^{bc}	80.40^{b}
with 0.3% CA	73.68^{fg}	63.45^{e}	8.48^{a}	9.82^{bc}	80.42^{b}
LSD	0.97	0.63	0.43	0.51	0.95

a-h Means in the same column with different letters are significantly different ($P \leq 0.05$)

Data in Table (5) indicate that raw and cooked low-fat beefburgers formulated by the combination between starches (75% fat replacement level controls) and CMC or CA had higher ($P \leq 0.05$) moisture contents than the 20% fat control and starches alone (the 75% fat replacement level controls). This is attributed to the increase in binding water by CMC or CA. Moisture content was increased with the increasing the level of CMC or CA. Compared to the 75% fat replacement level controls, addition of CMC or CA did not affect ($P > 0.05$) the fat content of raw low-fat beefburgers; however, significant ($P \leq 0.05$) reduction in fat content of cooked low-fat beefburgers was observed compared to the 20% fat control and 75% fat replacement level controls. Addition of CMC or CA to the starches showed similar ($P > 0.05$) fat retention to the 75% fat replacement level controls and higher ($P \leq 0.05$) fat retention than the 20% fat control.

Data in Table (6) indicate that addition of CMC or CA to the starches did not affect ($P > 0.05$) the pH values, while significant ($P \leq 0.05$) improvement in the cooking yield was observed compared to the 20% fat control and 75% fat replacement level controls. Similar improvement in cooking yield was reported by Mubarak (2001) for low fat beefburgers containing sodium alginate. Low-fat beefburgers formulated by combination between starches (75% fat replacement level controls) and CMC or CA had higher ($P \leq 0.05$) WHC and softer texture (low shear force) than the 20% fat control and at 75% fat replacement level controls. The combination between modified cornstarch and CMC or CA had higher ($P \leq 0.05$) WHC and lower shear force than the combination between tapioca starch and CMC or CA. The effect of gums in binding water was reported by several investigators (Berry, 1997, Troutt *et al.,* 1992 and Claus and Hunt, 1991).

Sensory properties for low-fat beefburgers as affected by the combination between starches (75% fat replacement level controls) and CMC or CA are presented in Table (7). The low-fat beefburgers formulated with CMC or CA at 0.1 % level showed similar ($P > 0.05$) tenderness, juiciness and overall acceptability as in the 75% fat replacement level controls. However, the low-fat beefburgers formulated with CMC or CA at 0.2% level showed similar ($P > 0.05$) tenderness, juiciness and overall acceptability as in the 20% fat control. At 0.1% level of CMC or CA, flavour intensity was similar

(P > 0.05) to the 20% fat control and 75% fat replacement level controls. However, flavour intensity was significantly (P ≤ 0.05) reduced at the higher levels of CMC or CA. Connective tissue was not affected (P > 0.05) by the addition of CMC or CA.

Table (6): Effect of different levels of carboxy methylcellulose (CMC) and calcium alginate (CA) on pH, cooking yield, water holding capacity and shear force of low-fat beefburgers

Fat replacement treatment	pH	Cooking yield (%)	WHC[1] (%)	Shear force (kg/g)
Control (20% fat)	6.76[a]	67.23[a]	62.19[a]	8.46[d]
Control (75% cornstarch)	6.74[a]	83.79[b]	75.32[b]	6.52[c]
Control (75% tapioca starch)	6.75[a]	83.72[b]	75.81[b]	6.86[c]
75% Modified cornstarch				
with 0.1% CMC	6.75[a]	87.13[c]	84.91[d]	4.76[a]
with 0.2% CMC	6.75[a]	88.55[d]	85.25[d]	4.60[a]
with 0.3% CMC	6.76[a]	89.12[de]	85.34[d]	4.50[a]
with 0.1% CA	6.75[a]	87.35[c]	85.78[d]	4.72[a]
with 0.2% CA	6.74[a]	88.90[de]	85.26[d]	4.65[a]
with 0.3% CA	6.74[a]	90.30[f]	85.33[d]	4.48[a]
75% Tapioca starch				
with 0.1% CMC	6.75[a]	86.90[c]	82.71[c]	5.46[b]
with 0.2% CMC	6.74[a]	88.62[d]	83.31[c]	5.38[b]
with 0.3% CMC	6.74[a]	89.74[ef]	83.36[c]	5.24[b]
with 0.1% CA	6.74[a]	86.81[c]	82.65[c]	5.56[b]
with 0.2% CA	6.75[a]	89.13[de]	83.28[c]	5.38[b]
with 0.3% CA	6.76[a]	89.85[ef]	83.38[c]	5.28[b]
LSD	0.08	1.01	1.11	0.41

[a-f]Means in the same column with different letters are significantly different (P ≤ 0.05)
[1]Water holding capacity

The textural profile analysis of the cooked low-fat beefburgers (Table 8) showed that the peak force (kg) needed for the first compression (hardness) was significantly ($P \leq 0.05$) decreased by replacing fat with starches alone (75% fat replacement level controls) or starches with CMC or CA combinations. The reduction of hardness is attributed to the higher moisture content of the low-fat beefburgers due to the combination effect of the starches with CMC or CA on binding water. Data of the second compression showed similar pattern to the first except that the peak force (kg) needed for the second compression was less than that for the first. Low-fat beefburgers were less resistant to compression by replacing fat with starches alone or starches with CMC or CA combinations. These results are in good agreement with those obtained by Crehan *et al.*, (2000) and Khalil (2000). Claus *et al.*, (1990) suggested that at higher levels of water, the muscle proteins interact with the water rather than form cross-bridges that would increase firmness of beef/pork bologna.

Springiness and cohesiveness were increased ($P \leq 0.05$) by replacing fat with starches alone or starches with CMC or CA combinations. Low-fat beefburgers formulated with starches alone were less ($P \leq 0.05$) springy and cohesive than those formulated with starches and CMC or CA combinations. Similar increase in springiness was reported by Crehan *et al.*, (2000) for low fat frankfurters containing different levels of maltodextrin. Springiness and cohesiveness were not affected ($P > 0.05$) by increasing the level of CMC or CA. Data indicated that modified cornstarch alone or in combination with CMC or CA were more effective ($P \leq 0.05$) in the reduction of hardness and increased springiness and cohesiveness than tapioca starch alone or its combination with CMC or CA.

From the above results it could be concluded that replacement fat content in regular beefburgers (20% fat) with modified cornstarch and tapioca starch alone at 75% fat replacement level increased the cooking yield, improved tenderness, juiciness and overall acceptability. Addition of CMC or CA to the modified cornstarch or tapioca starch proved to be more effective in increasing the cooking yield and WHC than modified cornstarch or tapioca starch alone. Addition of CMC or CA at 0.1% level showed similar ($P > 0.05$) tenderness, juiciness and overall acceptability as in the 75% fat replacement level controls. However, addition of CMC or CA at 0.2%

level showed similar (P > 0.05) tenderness, juiciness and overall acceptability as in the 20% fat control. Therefore, the low-fat beefburgers could be prepared by replacing fat content with the combination between modified cornstarch or tapioca starch at 75% fat replacement level and 0.1-0.2% CMC or CA.

Table (7): Effect of different levels of carboxy methylcellulose (CMC) and calcium alginate (CA) on sensory properties of low-fat beefburgers.

Fat replacement treatment	Tenderness	Juiciness	Flavour intensity	Connective tissue	Overall acceptability
Control (20% fat)	4.9^{b}	4.9^{b}	6.0^{f}	5.8^{a}	5.5^{cd}
Control (75% cornstarch)	6.6^{c}	6.8^{d}	6.1^{f}	5.8^{a}	6.2^{e}
Control (75% tapioca starch)	6.5^{c}	6.5^{cd}	6.1^{f}	5.8^{a}	6.1^{e}
75% Modified cornstarch -					
with 0.1% CMC	6.5^{c}	6.5^{cd}	5.9^{f}	5.8^{a}	6.1^{e}
with 0.2% CMC	4.8^{b}	4.9^{b}	5.3^{cde}	5.8^{a}	5.4^{c}
with 0.3% CMC	3.4^{a}	3.3^{a}	5.2^{cd}	5.8^{a}	4.8^{b}
with 0.1% CA	6.3^{c}	6.4^{cd}	5.7^{def}	5.8^{a}	6.0^{e}
with 0.2% CA	4.8^{b}	4.9^{b}	5.0^{bc}	5.8^{a}	5.4^{c}
with 0.3% CA	3.1^{a}	3.2^{a}	4.8^{bc}	5.8^{a}	4.6^{ab}
75% Tapioca starch					
with 0.1% CMC	6.2^{c}	6.3^{cd}	5.8^{ef}	5.8^{a}	6.0^{e}
with 0.2% CMC	4.9^{b}	4.9^{b}	5.2^{cd}	5.8^{a}	5.5^{cd}
with 0.3% CMC	3.2^{a}	3.1^{a}	4.5^{ab}	5.8^{a}	4.5^{ab}
with 0.1% CA	6.2^{c}	6.3^{cd}	5.6^{def}	5.8^{a}	5.9^{de}
with 0.2% CA	4.9^{b}	4.9^{b}	4.5^{ab}	5.8^{a}	5.4^{c}
with 0.3% CA	2.9^{a}	2.8^{a}	4.2^{a}	5.8^{a}	4.3^{a}
LSD	0.5	0.5	0.5	0.4	0.4

Means in the same column with different letters are significantly different ($P \leq 0.05$).

Table (8): Textural profile analysis of low-fat beefburgers as affected by the addition of carboxy methylcellulose (CMC) and calcium alginate (CA)

Fat replacement treatment	1st Compression hardness (kg)	2nd Compression Hardness (kg)	Total energy 1st Compression	Total energy 2nd Compression	Springines %	Cohesiveness %
Control (20% fat)	8.21^{e}	6.95^{e}	7.61^{a}	2.13^{a}	64.95^{a}	27.99^{a}
Control (75% cornstarch)	6.70^{c}	5.85^{c}	9.73^{c}	3.08^{c}	73.85^{c}	31.65^{c}
Control (75% tapioca starch)	7.11^{d}	6.18^{d}	8.81^{b}	2.69^{b}	72.13^{b}	30.53^{b}
75% Modified cornstarch						
with 0.1% CMC	5.80^{a}	4.35^{a}	11.72^{e}	4.20^{e}	77.68^{e}	35.84^{e}
with 0.2% CMC	5.67^{a}	4.43^{a}	11.51^{e}	4.09^{e}	77.32^{e}	35.53^{e}
with 0.3% CMC	5.69^{a}	4.31^{a}	11.43^{e}	4.05^{e}	77.20^{e}	35.43^{e}
with 0.1% CA	5.82^{a}	4.42^{a}	11.80^{e}	4.23^{e}	77.52^{e}	35.85^{e}
with 0.2% CA	5.72^{a}	4.33^{a}	11.19^{e}	3.98^{e}	77.41^{e}	35.57^{e}
with 0.3% CA	5.64^{a}	4.34^{a}	11.04^{e}	3.89^{e}	77.18^{e}	35.24^{e}
75% Tapioca starch						
with 0.1% CMC	6.19^{b}	5.23^{b}	10.45^{d}	3.48^{d}	75.48^{d}	33.30^{d}
with 0.2% CMC	6.25^{b}	5.13^{b}	10.72^{d}	3.61^{d}	75.32^{d}	33.68^{d}
with 0.3% CMC	6.14^{b}	5.25^{b}	10.59^{d}	3.55^{d}	75.21^{d}	33.52^{d}
with 0.1% CA	6.32^{b}	5.35^{b}	10.76^{d}	3.63^{d}	75.40^{d}	33.74^{d}
with 0.2% CA	6.35^{b}	5.29^{b}	10.60^{d}	3.56^{d}	75.28^{d}	33.58^{d}
with 0.3% CA	6.18^{b}	5.19^{b}	10.60^{d}	3.55^{d}	75.18^{d}	33.49^{d}
LSD	0.27	0.25	0.24	0.35	0.83	0.71

$^{a-e}$Means in the same column with different letters are significantly different ($P \leq 0.05$)

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تأثير بدائل الدهون ذات الأصل الكربوهيدراتى على صفات جودة البرجر البقري منخفض الدهن

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ملخص

تلعب الدهون دوراً هاماً فى إكساب المنتج الغذائي الصفات المميزة له مثل النكهة والقوام. ولكن نظراً للمخاطر الصحية التى يسببها الأفراط فى تناول الدهون وخاصة المشبعة منها فقد أتجهت الأبحاث حديثاً لمحاولة إنتاج منتجات غذائية منخفضة الدهن باستخدام بدائل الدهون. استخدمت فى هذا البحث بدائل الدهون ذات الأصل الكربوهيدراتى (نشا الذره المحور - نشا التابيوكا - دكسترين التابيوكا) لإحلال نسب مختلفة من الدهن (٢٥، ٥٠، ٧٥، ١٠٠%) لإعداد برجو بقرى منخفض الدهن. وقد درست خواص البرجر الناتج وذلك لتحديد أفضل نوع ونسبة من بدائل الدهون ليتم خلطها مع نسب مختلفة من كاربوكسى ميثيل سيليلوز أو الجينات الكالسيوم (٠,١، ٠,٢، ٠,٣%) وقد أوضحت النتائج المتحصل عليها ما يلي:

١- البرجر منخفض الدهن والمحضر بإضافة نشا الذرة المحور أو نشا التابيوكا كان أكثر قدرة على الاحتفاظ بالماء وأعطى عائد طبخ أعلى وكان أكثر قبولاً من البرجر المحضر بإضافة دكسترين التابيوكا.

٢- كانت نسبة ٧٥% هي أفضل نسبة لإحلال للدهن وذلك بناءاً على المقدرة على الاحتفاظ بالماء وعلى الخواص الحسية للبرجر منخفض الدهن.

٣- تم إضافة كاربوكسى ميثيل سيليلوز أو الجينات الكالسيوم للبرجر منخفض الدهن والمحضر بإحلال الدهن بنسبة ٧٥% باضافة كل من نشا الذرة المحور أو نشا التابيوكا وأدى ذلك لزيادة المقدرة على الاحتفاظ بالماء وزيادة عائد الطبخ وانخفاض shear force بالمقارنة بالبرجر المحتوى على ٢٠% دهن (العينة المقارنة) أو البرجر منخفض الدهن والمحضر بإحلال الدهن بنسبة ٧٥% بإضافة كل من نشا الذرة المحور أو نشا التابيوكا.

٤- إضافة كاربوكسى ميثيل سيليلوز أو الجينات الكالسيوم بنسبة ٠,١% أعطى برجر ذو خواص حسية مشابهة للبرجر منخفض الدهن والمحضر بإحلال الدهن بنسبة ٧٥%، بينما إضافة كل من هما بنسبة ٠,٢% أعطى برجر ذات خواص حسية مشابهة للبرجر المحتوى على ٢٠% دهن (العينة المقارنة).

٥- أظهرت دراسة خواص القوام أن إحلال الدهن بنسبة ٧٥% بإضافة نشا الذرة المحور أو نشا التابيوكا بمفردهما أو مع إضافة كاربوكسى ميثيل سيليلوز أو الجينات الكالسيوم أدى لخفض hardness وزيادة كل من springiness, cohesiveness

كما أوضحت نتائج الدراسة إنه يمكن إنتاج برجر بقرى منخفض الدهن وذو صفات جودة عالية بإحلال الدهن بنسبة ٧٥% بنشا الذرة المحور أو نشا التابيوكا مع كاربوكسى ميثيل سيليلوز أو الجينات الكالسيوم بنسبة ٠,١-٠,٢%.

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