SHORT COMMUNICATION

EFFECTS OF REGULAR AND MODIFIED POTATO AND CORN STARCHES ON FRANKFURTER TYPE PRODUCTS PREPARED WITH VEGETABLE OIL

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ABSTRACT

The effects of regular and modified potato and corn starches on improving meat batters prepared with 20% canola oil were investigated. Five of the six modified starches significantly reduced cooking loss as compared to control. The native corn did not, and its microstructure revealed incomplete gelatinization during cooking. One of the modified corn starches was totally incompatible with the meat matrix, resulting in low hardness, yield and incoherent microstructure. Fat loss was low, but reduced/eliminated by starch. Color was slightly affected by starch, but no major trend was observed. Overall, processors should carefully evaluate the functionality of starch they employ.

Keywords: frankfurters, meat, microstructure, starch, texture

1. INTRODUCTION

Meat processors use different non-meat ingredients for reasons such as improving water/fat binding, enhancing texture, sliceability, flavor, appearance, and controlling cost (BARANOWSKA *et al*., 2004; BREWER, 2012). The functional non-meat ingredients range from proteins (e.g., soy, milk) to carbohydrates (e.g., wheat flour, carrageenan), and spices (BARBUT, 2015). Starches, derived from various sources (e.g., corn, potato, tapioca), represent one of the most diverse groups of non-meat ingredients used to bind water, enhance freeze-thaw stability, and improve sliceability. In general, starch is a naturally occurring substance which is also used as a thickening agent in sauces, yogurt, and emulsion type products (BARANOWSKA *et al*., 2004). Different starches are available for industrial application in their natural form or as modified starches; the former type usually have more limited use in meat products. Overall, starch functionality may vary due to different botanical origins (e.g., potato, corn, tapioca, rice, pea) and modifications (e.g., enzyme, acid, heat) applied by the food industry (AKTAŞ and GENÇCELEP, 2006). Some meat products such as fish surimi have traditionally been produced with starch to increase firmness and water binding especially in such a highly minced, high water added product (VERREZ-BAGNIS *et al*., 1993; FOGAÇA *et al*., 2013). In other red meat/poultry products, starches are used to enhance gel strength and water holding, to replace fat, and control formulation cost (LI and YEH, 2003a, b; BREWER, 2012). DEXTER *et al*. (1993) reported that starch added to turkey bologna was very effective in decreasing purge while not increasing hardness. They also reported that starch effect depended on the type of starch used, water-to-starch ratio, processing factors, and presence of ingredients such as fat. Modified potato starch was reported to improve the texture of low fat bologna (CLAUS and HUNT, 1991) and comminuted scaled sausage (PIETRASIK, 1999). CARBALLO *et al*. (1995) indicated that adding starch to meat emulsions resulted in more compact and stronger heat induced meat protein network. RESCONI *et al*. (2015) reported that using rice starch (0.3-1.5%) helped increase yield and hardness of whole muscle cooked hams.

Replacing animal fat with vegetable oil is another significant trend seen today, and additives such as starch are important in stabilizing the high moisture added to reduced fat meat products (BREWER, 2012; BARBUT *et al*., 2016). Currently there are some starch suppliers that claim that their products can also enhance fat stabilization in meat products. Therefore, the objectives of this study were to compare the effects of potato and corn starches in their native and modified forms (total 8 starches) on cooking losses (moisture and fat), texture, microstructure, and color of emulsified meat products prepared with vegetable oil.

2. MATERIALS AND METHODS

2.1. Preparation of meat batters

Lean shoulder blade beef meat was obtained from the University of Guelph abattoir. All visible connective tissue and fat were removed from the lean meat. Meat was comminuted in a bowl chopper (SMK 40; Schneidmeister, Berlin, Germany) at the low speed setting for 1 min to obtain a homogenous mass. The meat (73.6% moisture, 19.6% protein, and 5.9% fat. AOAC, 1996) was vacuum-packed and frozen (-18ºC) in polyethylene bags (750g/package) for up to 1 month prior to use. Nine different formulas were prepared in 3 independent trials. The starches used include native potato (NP) starch (Herman Laue Spice Co., Uxbridge, ON, Canada), modified potato starch-1 (MP-1, PenCling 530; Penford

Food Ingredients Co., Denver, CO, USA), modified potato starch-2 (MP-2, Farinex VA 15; Avebe Foods, Veendam, Netherlands), modified potato starch-3 (MP 3, Eliane VE 420; Avebe Foods, Veendam, Netherlands), native corn starch (NC, Amioca; National Starch, Westchester, IL, USA), modified corn starch-1 (MC-1, Em-Cap; Cargill Inc., Minneapolis, MN, USA), modified corn starch-2 (MC-2, PenCling 570; Penford Food Ingredients Co., Denver, CO, USA), modified corn starch-3 (MC-3, Firm-Tex; National Starch, Westchester, IL, USA), and a control with no starch (CONT). Meat was thawed at 5ºC overnight. Pure canola oil (No Name®; Sunfresh Limited, Toronto, ON, Canada), was used as the main fat source. The batters were formulated to contain 25% fat/oil (5.9% as beef fat within the lean meat, and the rest added as canola oil), 13.5% protein and 2% starch in all treatments except no starch in the control. Meat was initially chopped at the low speed setting for 30 s. Later, while chopping at the high speed setting for 30 s, 2.0% salt and 0.25% sodium tripolyphosphate were added. This was followed by a 2 min break (for protein extraction to occur). Next, canola oil and the appropriate starch (prepared by dissolving the starch in the 2% water added to the product) were added to the batter while chopping at the high speed setting for 1 min, followed by ice addition and further chopping for 4 min. The temperature of the batter did not exceed 12ºC in any of the treatments. Each batter was vacuum-packed (Multivac model A300/16; Wolfertschwenden, Germany) to remove trapped air. For each batter, 35g samples were stuffed into three separate 50 ml polypropylene tubes, which were centrifuged (Model 224; Fisher Scientific, Pittsburgh, PA, USA) at the low speed setting for 30 s to remove any remaining small air bubbles. The batters were cooked in a water-bath (W-26; Haake, Berlin, Germany) from 25 to 70ºC within 1.5 h. A thermocouple unit was used to monitor the core temperature of the samples (Model 52 KJ1, Fluke, Everett, WA, USA).

2.2. Cooking loss

Test tubes were cooled in ice water for 5 min, and then liquid separated during the cooking cycle was collected and expressed as % cooking loss (liquid expelled (g)/raw batter weight (g) x 100). The next day the volume of the fat (floated to the top overnight) separating out was determined and expressed as fat loss.

2.3. Texture profile analysis (TPA)

After an overnight storage (5°C), TPA parameters were determined using nine cooked cores (each 16 mm diameter and 10 mm high) per treatment. Cores were compressed twice to 75% of their original height by a texture analyzer (Stable Micro Systems, Model TA.XT2; Texture Technologies Corp., Scarsdale, NY, USA) at a crosshead speed of 1.5 mm/s. The following parameters were determined: hardness, springiness, cohesiveness, chewiness, and gumminess (ROSENTHAL, 2010).

2.4. Color

The color of fresh cut cross-sections of the cooked meat batters (9 per treatment) was determined (Mini Scan MS/S; Hunter Laboratories, Reston, VA, USA) using the D65 illuminant setting, and 10-degree standard observer. Color is expressed according to the Commission International de l'Eclairage (CIE) system and reported as Hunter L* (lightness), a* (redness), and b* (yellowness) (WIEGAND and WALOSZEK, 2003).

2.5. Microstructure

Samples (2.0×2.0×0.5 cm) were cut from the centers of cooked meat batters, fixed in 10% neutral buffered formalin for 10 h at room temperature, dehydrated in 70% isopropanol for 2 h, 95% for 1 h, and 100% for 4 h and embedded in paraffin. Samples were cut into 4-6 μm sections, stained with hematoxylin-eosin for 4 min, and observed using a light microscope (Model BX60F5; Olympus Optical Company, Tokyo, Japan). Black and white pictures were taken (Image-Pro Plus, Version 5.1; Media Cybernetics Inc., Silver Spring, MD, USA).

2.6. Statistical analysis

The experiment was designed as a complete randomized block, with three separate replications. Statistical analysis was performed using a software package (SAS version 8.02; SAS Institute, Cary, NC, USA). The SAS General Linear Model procedure was used for analysis of variance. Tukey's multiple comparison analysis was performed to separate the means ($p < 0.05$).

3. RESULTS AND DISCUSSION

The addition of all four potato starches resulted in a significant reduction in cooking loss compared to the control (Table 1).

Table 1. Effects of native and modified starches on overall cooking loss, fat loss, moisture loss and color parameters (L*=lightness, a*=redness, b*=yellowness) of meat batters prepared with canola oil.

Treatment* (#)	Cooking loss (%)	Fat loss (%)	Moisture loss (%)	Color coordinates (Lightness)	(Redness)	(Yellowness)
1 CONT	2.26±0.29^{b}	0.57±0.18^{a}	1.69±0.26^{b}	65.4±0.30^{b}	3.60±0.03^{c}	13.2±0.08^{b}
2 NP	0.67±0.09^{d}	0.14±0.05^{b}	0.53±0.10^{c}	63.9±0.16^{c}	3.93±0.03^{a}	13.3±0.05^{ab}
3 MP-1	0.44±0.12^{d}	0.12±0.06^{b}	0.32±0.06^{c}	62.9±0.28^{d}	4.04±0.03^{a}	13.2±0.09^{b}
4 MP-2	0.19±0.07^{d}	0.00±0.00^{b}	0.19±0.07^{c}	63.1±0.22^{d}	3.91±0.04^{a}	13.2±0.07^{b}
5 MP-3	0.29±0.07^{d}	0.00±0.00^{b}	0.29±0.07^{c}	62.4±0.27^{d}	4.00±0.03^{a}	13.2±0.09^{b}
6 NC	1.86±0.20^{bc}	0.19±0.09^{b}	1.67±0.11^{b}	65.0±0.27^{b}	3.69±0.04^{bc}	13.3±0.10^{ab}
7 MC-1	5.89±0.44^{a}	0.00±0.00^{b}	5.89±0.44^{a}	66.5±0.34^{a}	3.35±0.05^{d}	13.5±0.11^{a}
8 MC-2	1.10±0.68^{cd}	0.00±0.00^{b}	1.10±0.68^{bc}	62.4±0.29^{d}	4.04±0.05^{a}	13.2±0.10^{b}
9 MC-3	0.25±0.06^{d}	0.06±0.04^{b}	0.19±0.03^{c}	63.1±0.26^{d}	3.78±0.02^{b}	13.1±0.08^{b}

$^{a-d}$means, ± standard error, with no common superscript are significantly different ($p < 0.05$).
*all formulated with 2.0% salt and 0.25% sodium tri-polyphosphate. CONT = Control; NP = Native Potato starch; MP = Modified Potato starch; NC = Native Corn starch, MC = Modified Corn starch.

This can be correlated to starch molecules opening up, during heating, and absorbing moisture; a process known as gelatinization (BARANOWSKA *et al*., 2004). In the case of the added corn starches (Treatments 6-9), the native corn starch did not show a significant improvement over the control. Examination of the micrographs shows that this treatment did not reach the gelatinization point (i.e., granules shown as compact non-open structures; Fig. 1F).

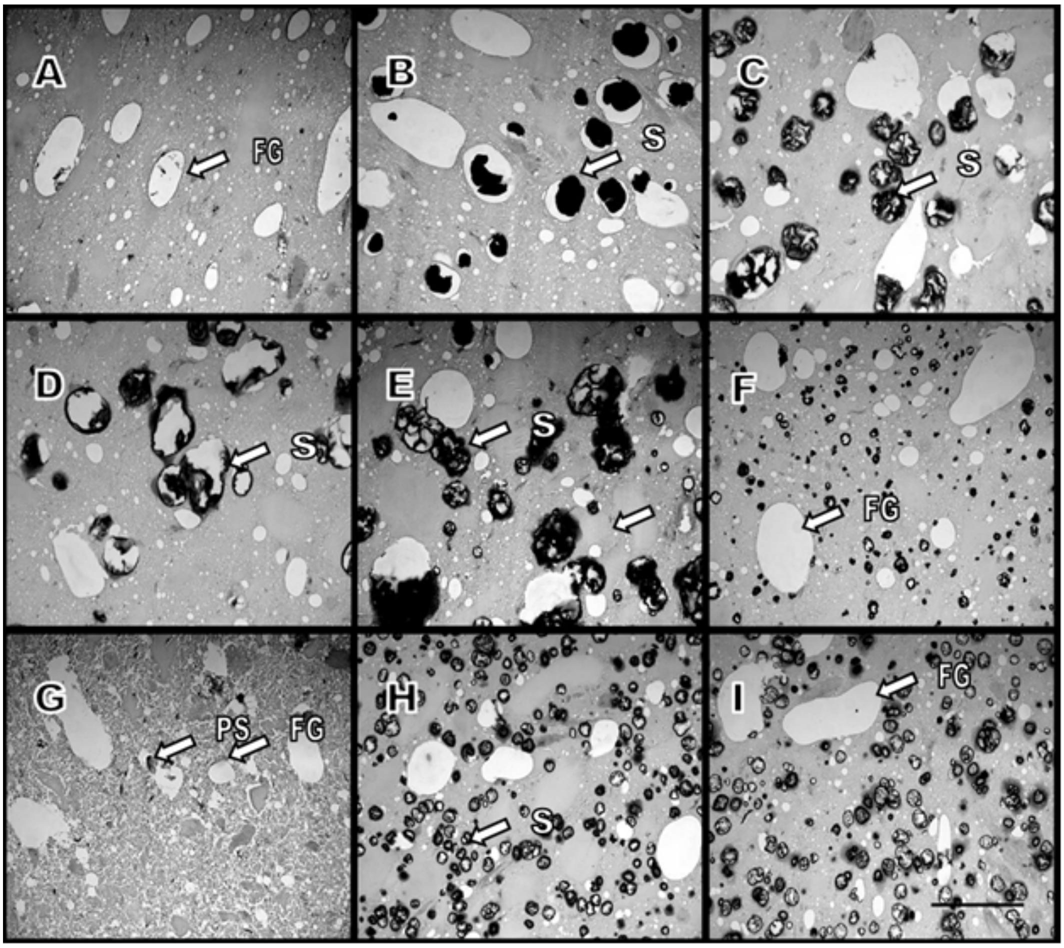

Figure 1. Light micrograph of cooked meat batters (13.5% protein) prepared with canola oil and different starches: (A) control; (B) native potato starch (C) modified potato-1 (MP-1); (D) MP-2; (E) MP-3; (F) native corn; (G) modified corn-1 (MC-1); (H) MC-2; and (I) MC-3. FG-fat globules (i.e., fat removed during sample preparation; prior to paraffin embedding); S-starch; PS-probably starch. Bar = 200μm.

This is the reason that quite a few of the starches used by the meat industry are pre-gelatinized, meaning that they are pre-exposed to a certain heat treatment; i.e., to open or partially open their structure and make them capable of absorbing water even at a low temperature (BARANOWSKA *et al.*, 2004; RESCONI *et al.*, 2015). A certain degree of unopened structures is also seen in the MC-2 treatment (Fig. 1H) where a number of very dense non-gelatinized starch granules can still be seen after heating the meat batter to 70°C. The MC-2 and MC-3 treatments resulted in a significant reduction in cooking loss compared to the control (2.26 vs. 1.10, a 50% reduction and 0.25, a 90% reduction, respectively). The MC-1 treatment showed the highest cooking loss value (Table 1) and revealed extremely small starch granules. However, the high cooking loss seems to be related to the disruption of the entire microstructure (Fig. 1G) as seen by the many open channels (discontinuities) and gaps within the matrix. This kind of microstructure has also negatively affected the texture (e.g., hardness, springiness; see below). It should be mentioned that describing the nature of the starches' modifications (provided by the manufacturers) is very vague. As a result, it is difficult to relate the modifications to specific effects in the meat system.

In terms of fat loss, although relatively low in the control (0.5%), all starches helped to lower or eliminate it. This is most likely due to the starch increasing the viscosity of the meat batters rather than actually binding the fat. Overall, the fat/oil was held very well within the meat matrix of the control (Fig. 1A). The micrograph shows small, stable, and well distributed fat globules, and is in agreement with previously published micrographs (BARBUT *et al*., 2016). The addition of starch did not show any interference with the stability of the fat globules and/or any direct interaction with the fat phase. The slight improvement in fat retention seen here is also in agreement with AKTAS and GENÇCELEP (2006), who noted that some modified potato and corn starches can reduce fat loss from bologna type sausage produced with sheep tail fat.

Table 2. Effects of native and modified starches on texture profile parameters of cooked beef meat batters prepared with canola oil.

Treatment* (#)	Hardness (N)	Springiness (cm)	Cohesiveness (ratio)	Chewiness (N x cm)	Gumminess (N)
1 CONT	67.6±1.5^{c}	0.81±0.01^{a}	0.39±0.01^{a}	21.5±0.8^{a}	26.5±0.7^{ab}
2 NP	79.4±2.2^{a}	0.75±0.01^{b}	0.35±0.01^{b}	21.3±0.9^{a}	28.3±1.1^{a}
3 MP-1	68.1±1.7^{bc}	0.73±0.02^{bcd}	0.30±0.01^{d}	15.1±0.6^{cd}	20.4±0.5^{cd}
4 MP-2	64.9±1.2^{cde}	0.74±0.01^{bc}	0.29±0.01^{d}	14.1±0.4^{d}	19.0±0.4^{d}
5 MP-3	62.9±1.4^{def}	0.69±0.01^{d}	0.26±0.01^{e}	11.6±0.43^{e}	16.6±0.5^{e}
6 NC	72.2±1.6^{b}	0.76±0.01^{b}	0.34±0.01^{b}	19.3±0.7^{b}	25.2±0.7^{b}
7 MC-1	59.5±1.4^{f}	0.59±0.02^{e}	0.29±0.01^{d}	10.1±0.2^{e}	17.1±0.3^{e}
8 MC-2	66.3±1.1^{cd}	0.76±0.01^{b}	0.31±0.01^{c}	16.1±0.4^{c}	21.0±0.5^{c}
9 MC-3	61.0±1.2^{ef}	0.70±0.01^{cd}	0.27±0.01^{e}	11.7±0.5^{e}	16.5±0.5^{e}

$^{a-f}$means, ± standard error, with no common superscript are significantly different ($p < 0.05$).
*all formulated with 2.0% salt and 0.25% sodium tripolyphosphate. CONT = Control; NP = Native Potato starch; MP = Modified Potato starch; NC = Native Corn starch, MC = Modified Corn starch.

Texture profile analysis results (Table 2) show that using the two native starches (potato and corn) significantly increased hardness values above the ones seen in the control. VERREZ-BAGNIS *et al*. (1993) and LI and YEH (2003a) also reported that adding native starch to meat products increased hardness/storage modulus. The other modified starches either did not influence hardness or caused a reduction. SANJEEWA *et al*. (2010) reported that in some of the Canadian varieties of chickpea flours (contain 36-41% starch) they added to low-fat bologna, they observed increased TPA hardness values, while in others they did not. In the present study, the lowest hardness value was seen in the MC-1 treatment, which also lost the highest amount of water. As indicated earlier, this is probably due to formation of channels/disruptions within the meat matrix (Fig. 1G), and resulted in a weaker physical structure. A similar result was also observed for the springiness value, which was the lowest for this treatment (Table 2). Overall, the control (no starch) showed the highest springiness value. All starches caused the formation of less elastic cooked meat structures as evidenced by the lower springiness value (Table 2). This might be due to some discontinuities imparted by the starch (gelatinized or still granular) within the meat matrix. The same was observed for cohesiveness values. However, it should be mentioned that differences between the starches exist and the two native starches (potato and corn) resulted in higher values than the modified starches. Chewiness and gumminess followed the same trend in which the native potato starch was actually not significantly different from the control, but both native starches (potato and corn) resulted in higher values compared to the modified starches. This could be due to more

interactions of the modified starches with meat proteins (i.e., because some are pre-gelatinized and can interact with the proteins before they become heat denatured; BARBUT, 2015). However, this point needs further investigation.
The color of the potato starch added treatments was not as light as the one in the control (lower L* values; Table 1). However, the difference of about 2 L* units (scale: 0=black, and 100=pure white) should not be expected to cause a major obstacle in terms of consumer acceptance. In the case of corn starch, the MC-1 ended up lighter than the control, and MC-2 and MC-3 were darker. Again these differences are not expected to be a problem in terms of marketing. Red color (a*) did not show a major change except for the MC-1 treatment which had the highest cooking loss values (i.e., twice as high as the control; Table 1). This resulted in more of the water soluble red pigment (myoglobin) leaching out of the product. Yellowness values were basically unchanged by starch addition.

4. CONCLUSIONS

The study demonstrates the positive effect of using modified potato and corn starches in an emulsified meat product. The MP-2 showed the best performance in terms of minimum cooking loss and hardness compared to the control. The study also highlights the fact that attention should be given to starch selection for a specific application. In addition, it should be mentioned that some ingredient suppliers sell blends of 2-3 starches to cover various aspects within the same formula, and the meat processor should be aware of the composition, cost, and added value of each component.

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