Effect of shaddock albedo addition on the properties of frankfurters

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Abstract To explore the potential as a natural auxiliary emulsifier, shaddock albedo was added into frankfurters at six different levels: 0.0, 2.5, 5.0, 7.5, 10 and 12.5 %. The emulsion capacity (EC) of meat batters and cooking properties of frankfurters were evaluated. EC of meat batters was improved with the addition of shaddock albedo and the maximum value was reached at the 5 % albedo concentration. The addition of shaddock albedo resulted in lower cooking losses of frankfurters, with the lowest value obtained at the 7.5 % level. The presence of shaddock albedo decreased the total expressible fluid (TEF) and the proportion of fat in total expressible fluid (PF) which indicated the emulsion stability of frankfurters and the lowest values both occurred at the concentration of 7.5 %. Shaddock albedo inclusion increased the lightness and yellowness of frankfurters and decreased redness. Texture profile analysis showed increased hardness and decreased chewiness of frankfurters with the addition of shaddock

albedo. Consequently, shaddock albedo could be a potential source of auxiliary emulsifier filler for emulsion-type meat products.

Keywords Shaddock albedo · Frankfurters · Emulsion capacity · Cooking loss

Introduction

Emulsion-type meat products are of fairly homogeneous texture upon heat denaturation of the finely comminuted mixture of muscle proteins and fat particles. Frankfurter is one of the most popular emulsion-type meat products consumed at home and especially in fast food outlets (Ashton and Barbut 1992). Meat batter of emulsion-type meat products is an emulsion system in which salt-soluble proteins function as emulsifiers to stabilize the fat drops in the comminuted mixture. During chopping, the formation of a protein film around the fat particles allows fat to be retained inside the protein matrix. Certain attractive forces contribute to holding the raw materials together to create a homogeneous matrix structure (Allais et al. 2004; Barbut 1998). Inadequate soluble protein extraction and an excessive reduction of fat particle size can lead to reduced emulsification ability, which might lead to the aggregation of fat globules in sausages, and thereby cause the deterioration of the product (Nieto et al. 2009). As a result, the concentration of soluble proteins extracted from muscle tissues and their emulsion properties are important for acceptable and viable meat products. Many researchers have focused on the improved stabilization of meat batters and emulsion capacity of soluble proteins (Ashton and Barbut 1992; Sariçoban et al. 2008, 2010).

Polysaccharides are potential emulsifiers or auxiliary emulsifiers and many polysaccharide substances have been investigated for improving stabilization of meat batters: e.g.

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carrageenan (Flores et al. 2007), xanthan gum (Barbut and Mittal 1992) and pectin (Candogan and Kolsarici 2003). Pectins are a class of complex polysaccharides abundant in apple pomace and citrus peels (Thakur et al. 1997). The negatively charged carboxylate groups of pectin, especially low-methoxyl pectin, have potential to interact with positively charged muscle protein residues (Imeson et al. 1977; Ledward 1979). Therefore, pectin can be expected to improve the emulsifying properties of proteins through electrostatic repulsion caused by the accumulation of negative charge to protein molecules (Sarıçoban et al. 2010).

Shaddock, *Citrus grandis Osbeck*, is a crisp citrus fruit native to South and Southeast Asia (Morton 1987). At present, the annual output of shaddock in China reaches about three million tonnes, ranking first in the world. The by-products of shaddock, mainly peels and albedo, contain the most pectin (8.5 %) among all citrus fruits (Marín et al. 2003), and represents a considerable source of pectin. It has considerable potential for utilization in meat products.

The objective of this work was to explore the potential of shaddock albedo as natural auxiliary emulsifier fillers in frankfurters. Shaddock albedo at levels of 0.0, 2.5, 5.0, 7.5, 10.0 and 12.5 % were added into frankfurters. The properties of meat batters and the quality characteristics of frankfurters influenced by addition of shaddock albedo were studied.

Materials and methods

Shaddock albedo preparation

Fresh shaddocks at full ripeness were bought from the local market. After ripping off the yellow skin, albedo was minced using a homogenizer (CF-04, Taizhou Chengliang machinery Co., LTD, Zhejiang Province, China) to produce a homogeneous material. The mean dimension of the minced albedo particles was 0.875 mm determined by a particle size analyzer (LS230, Beckman Coulter, USA). Before being added to frankfurters, the homogeneous albedo material was vacuum-packed in polyethylene vacuum pouches (500 g) and immediately frozen at -18°C . When needed, albedo pouches were thawed in a refrigerator ($4\text{--}7^{\circ}\text{C}$) for 24 h.

Frankfurter manufacture

Frankfurters were manufactured according to a traditional formula (Table 1) at the pilot plant of China Agricultural University. Lean pork percentages add up to 100 % (1,000 g) and percentages of others ingredients are related to

lean meat: 50 % back fat, 45 % water (as ice form w/w), 12 % sugar (w/w), 3 % white pepper (w/w), 3 % sodium chloride (w/w), 0.45 % polyphosphate (w/w), 0.00225 % sodium ascorbate (w/w) and 0.025 % sodium nitrite (w/w). This formula without shaddock albedo was the control group and for the others frankfurters shaddock albedo was added at different levels: 2.5, 5.0, 7.5, 10.0 and 12.5 %.

The products were prepared according to industrial processing standards. After removing the surface fat and connective tissue, lean pork was cut into 5-cm-sided cubes and pre-soused with curing agent (3 % sodium chloride, 0.45 % polyphosphate, 0.00225 % sodium ascorbate and 0.025 % sodium nitrite) at 4°C for 2 days. A meat grinder (BJRJ-22, Expro Machinery Engineering Co. Ltd., Hangzhou, China) was used to make the lean meat and back fat homogeneous respectively and it was immediately tempered at 4°C overnight.

The pre-weighed lean meat (1,000 g per treatment) was transferred to a bowl cutter (BZBJ-130, Expro Machinery Engineering Co. Ltd.), adding 15 % ice and corresponding albedo, then chopped for 3 min to extract the soluble proteins. A 100-g aliquot of meat sample was taken from the system for emulsion capacity analysis. The pre-weighed back fat along with other ingredients were then added and chopped for a further nearly 6 min until the final chopping temperature reached 13°C . After homogenization, mixtures were stuffed into 22-mm diameter artificial casing (Collagen casing, Hebei kaisheng casing co., LTD) and tied at intervals of 10 cm. Frankfurters were then cooked in water bath until 72°C was reached at the geometric center of each chub and immediately cooled with cold water (12°C) to room temperature. After weighing, pouches of ten frankfurters were evacuated and heat-sealed and then stored at $4\pm 1^{\circ}\text{C}$ until analyzed. All trials of six treatments with three repeats were completed within 1 day.

Chemical and physicochemical analysis of frankfurters

Moisture, protein, fat and crude fiber content were determined by AOAC (2000) methods. Moisture (%) was determined by drying a 5-g sample at 105°C to constant weight. Protein (%) was analyzed according to the Kjeldahl method. A factor of 6.25 was used for conversion of nitrogen to crude protein. Fat was measured by weighing the extraction with petroleum in a Soxhlet apparatus (Fat analyzer SZF-06C, Top Instrument Co. Ltd., Hangzhou) accounting for the proportion of the frankfurter sample. Crude fiber (%) was determined by the Weende method. Residual nitrite level

Table 1 Frankfurter formulations with different treatment concentrations of shaddock albedo

Ingredient (g)	Treatments: concentrations of shaddock albedo (%)					
	0.0	2.5	5.0	7.5	10.0	12.5
Lean pork	1,000	1,000	1,000	1,000	1,000	1,000
Pork backfat	500	500	500	500	500	500
Shaddock albedo	0	25	50	75	100	125
Ice	450	450	450	450	450	450
Sugar	120	120	120	120	120	120
White pepper	30	30	30	30	30	30
Sodium chloride	30	30	30	30	30	30
Polyphosphate	4.5	4.5	4.5	4.5	4.5	4.5
Sodium ascorbate	0.0225	0.0225	0.0225	0.0225	0.0225	0.0225
Sodium nitrite	0.25	0.25	0.25	0.25	0.25	0.25

(mg NaNO₂/kg sample) was determined in agreement with standards ISO/DIS 2918 (ISO 1975).

Emulsion capacity (EC) determination of meat batters

Emulsion capacity of meat batters was determined with the methods described by Webb et al. (1970). Total batter extracts were prepared by adding a 20-g sample of the chopped meat as described above to 100 ml of distilled water. The mixture was mixed for 10 min at 500 rpm using a motor stirrer (JJ-1, Changzhou Guohua Electric Appliance Co. Ltd., Jiangsu Province, China). Salt-soluble supernatant extracts were obtained by taking an 80-ml aliquot of the prepared slurry and centrifuging twice for 10 min at 11 000×g. The final supernatant was stored for 1 h at 4 °C before determining emulsion capacity.

Emulsion capacity determinations were made by adding a 20-ml aliquot of sample extract to a 400-ml beaker. The stirrer was operated at 1,000 rpm during emulsifying. Refined soybean oil was delivered continuously through a constant flow pump (HL-2S constant-current pump, Shanghai Jiapeng Technology Co. Ltd., China) at a rate of 50 rpm (2.65 ml oil/min). Oil temperature was maintained at 30 °C. The electrical conductivity of the emulsion was monitored by a conductivity meter (LE703, Mettler Toledo, Sweden). At the breaking point, the conductivity suddenly dropped and oil addition was stopped. All trials were completed in triplicate. The total amount of emulsified oil was measured and calculated. EC value was calculated as ml of oil/g meat batter.

Hydration/binding properties determination of frankfurters

Hydration/binding properties represent the ability of the meat emulsion to retain moisture and fat upon further processing, which are usually indicated by cooking loss

and emulsion stability (Townsend et al. 1968). Cooking loss values were determined by calculating the weight difference of six chubs of frankfurters before and after cooking using the following equation:

$$\text{Cooking loss (\%)} = \left[\frac{\text{weight before cooking} - \text{weight after cooking}}{\text{weight before cooking}} \right] \times 100\%$$

Emulsion stability was measured by the method of Hughes et al. (1998). Approximately 25 g of the meat batters were transferred into a centrifuge tube (three replicates per formulation) and centrifuged for 5 min at 3,100×g using a TDL-5-A centrifuge (Shanghai Anting Science Instrument Factory, Shanghai, China) to make the batters smooth. The samples were heated in a water bath until 72 °C was reached at the geometric center and then centrifuged for 15 min at 3,100×g. The pelleted samples were removed and weighed and the supernatants poured into pre-weighed crucibles and dried overnight at 103 °C. The volumes of total expressible fluid (TEF) and proportion of fat in total expressible fluid (PF) were

$$\text{TEF} = \frac{\text{weight of centrifuge tube and sample} - \text{weight of centrifuge tube and pellet}}{\text{weight of sample}} \times 100\%$$

$$\text{TEF (\%)} = \left[\frac{\text{TEF}}{\text{sample weight}} \right] \times 100\%$$

$$\text{PF (\%)} = \frac{[(\text{weight of crucible} + \text{dried supernatant}) - (\text{weight of empty crucible})]}{\text{TEF}} \times 100\%$$

Color analysis of frankfurters

Instrumental color of frankfurters was measured at room temperature using a Chroma meter (CR-400, Konica Minolta Sensing Inc., Japan) with illuminant D₆₅, 2° observer, and 8 mm aperture size. The instrument was calibrated with a white reference tile ($Y=93.6$, $x=0.3159$, $y=0.3325$) before the measurements. According to the ISO/CIE standard color space system proposed by Commission Internationale de l'Eclairage (Joint ISO/CIE Standard, 2008), the L*, a* (±red—green) and b* (±yellow—blue) color coordinates were determined. According to AMSA guidelines (2012), samples with 12–15 mm thickness are sufficient to absorb non-reflected light. Therefore, all samples were sliced into 25 mm thickness after the casing has been removed. Measurements were taken directly on the surface of frankfurters. Five measurements for each of three replicates were taken.

Texture profile analysis of frankfurters

Texture of the cooked frankfurters was determined using TMS-Pro Texture Analyzer (Food Technology Corp., Sterling, Va., USA) as described by Wang et al. (2011). A probe with a diameter of 50 mm was used and the crosshead speed was 12 mm/min. Three cores with a diameter of 22 mm and a height of 10 mm were cut from each of two frankfurters per treatment. In the experiment, samples were compressed to 50 % of their original height and essential information on texture of frankfurters such as hardness, springiness, cohesiveness, adhesiveness and chewiness were recorded.

Statistical analysis

Conventional statistical methods were used to calculate reported means±standard deviations. Experimental data were subjected to one-way ANOVA and if this revealed significant differences ($p<0.05$), then Duncan's multiple-range test was performed using SPSS Statistics 17.0 (Chicago, IL, USA).

Results and discussion

Chemical and physicochemical properties of frankfurters

The chemical and physicochemical properties of frankfurters are presented in Table 2. Proximate analysis indicated that any

inclusion of shaddock albedo increased moisture content and decreased protein content and fat content (all $p<0.05$). The moisture increase could result from the dietary fiber, mainly pectin, in the albedo that may retain water released from the meat matrix during cooking (Fernández-Ginés et al. 2004). Component analysis showed that shaddock albedo contained 80.2 ± 0.2 % moisture and 16.8 ± 0.6 % dietary fiber, which included 8.6 % pectin.

Nitrite added to formulations is reduced to nitric oxide, which reacts with myoglobin to form nitric oxide myoglobin, and gives meat products a red color (Pegg and Shahidi 1996). The values of residual nitrite level correspond to available nitrite that has not reacted with ingredients in meat products such as myoglobin. The incorporation of shaddock albedo in frankfurters caused a significant decrease ($p<0.05$) in residual nitrite (Table 2), and the more albedo added, the higher the reduction – this reduces the possibility of nitrosamine formation, a considerable risk to consumer health. The high reactivity of biocompounds in the shaddock albedo may have been responsible for this reduction in residual nitrite. The antioxidant properties of shaddock albedo have been previously reported (Jang et al. 2010; Mokbel and Hashinaga 2006).

Emulsion capacity of meat batters with different additions of shaddock albedo

Meat proteins function as emulsifiers in sausage-type emulsions and the capacity of this function can be indicated by the value of emulsion capacity. Shaddock albedo addition increased the EC values of meat batters (Fig. 1). EC reached a peak at the concentration of 5 % albedo, which was in accordance with the work of Sarıçoban et al. (2008) who revealed that the emulsion capacity of chicken meat increased with lemon albedo addition up to a concentration of 5 % and decreased thereafter. The soluble components pectin presented in shaddock albedo made this phenomenon can be expected. The formation of protein–polysaccharide complexes between pectin and myofibrillar proteins can be employed to improve functional properties of myofibrillar proteins (Sarıçoban et al. 2010). However, organic acids, mainly phenolic and ascorbic acids, in shaddock albedo give it a low pH value of 4.53 (Braddock 1995; Wang et al. 2008). With the addition of shaddock albedo, the linear decrease of pH – one of the most important parameters affecting emulsion characteristic (Cheftel et al. 1985) – caused proteins to approach the isoelectric point where they had the least EC and solubility. Therefore, EC values decreased for shaddock albedo concentration > 5.0 %.

Table 2 Chemical composition of frankfurters formulated with different treatment concentrations of shaddock albedo^a

Treatment (%)	Moisture (%)	Fat (%)	Protein (%)	Nitrite (mg NaNO ₂ /kg)
0.0	56.6±0.3 ^c	17.5±0.3 ^d	15.2±0.9 ^a	24.56±0.88 ^a
2.5	57.2±0.4 ^b	18.0±0.6 ^c	13.6±0.6 ^c	20.97±1.94 ^b
5.0	58.3±0.4 ^a	18.6±0.3 ^b	13.6±0.1 ^c	18.44±1.25 ^b
7.5	58.1±0.5 ^a	19.3±0.4 ^a	13.6±0.3 ^c	14.32±0.56 ^c
10.0	56.7±0.2 ^c	17.9±0.4 ^{cd}	14.6±0.5 ^b	12.28±0.44 ^{cd}
12.5	57.9±0.5 ^a	16.8±0.3 ^e	14.6±0.3 ^b	11.30±0.31 ^d

^a Different letters in the same column indicate significant differences ($p<0.05$)

Hydration/binding properties

The addition of shaddock albedo decreased ($p<0.05$) the cooking loss of frankfurters up to a concentration of 7.5 % (Table 3). This phenomenon could be explained by the fact that the fiber, especially pectin, in albedo has great water and fat holding capacity. With further addition of shaddock albedo, cooking loss of frankfurters increased ($p<0.05$) at the concentration of 10 %. This may be due to the lower pH decreasing the emulsion capacity of meat protein and destabilizing the meat batter system (Cheftel et al. 1985; Sariçoban et al. 2008). Lin and Huang (2003) believed that lower pH decreased total negative charges of myofibrillar proteins and the water-binding capacity of meat. The decreased cooking loss at the concentration of 12.5 % could be due to the effect of water and fat holding behavior of diet fiber exceeding the negative effect of decreased emulsion capacity caused by low pH.

The presence of shaddock albedo decreased the TEF – the lowest value was at the concentration of 7.5 % and was significantly different to controls. There were no significant differences in PF between frankfurters formulated with different levels of shaddock albedo, consistent with the results of Sariçoban et al. (2008) who found that the increased albedo concentration did not influence the emulsion stability values. Frankfurters with 12.5 % shaddock albedo had significantly

higher PF than controls, probably due to the low pH destabilizing the meat batters.

Color characteristics

Shaddock albedo is a white, spongy component of shaddock fruit, with high lightness ($L^*=83.7$) and yellowness values ($b^*=14.2$) and low redness value ($a^*=-1.7$). The addition of shaddock albedo could change the color characteristics of meat products. Lightness (L^*) and redness (a^*) of cooked frankfurters were significantly ($p<0.05$) affected by the concentration of albedo, as well as yellowness (b^*) (Table 4) – this differed to the results of Fernández-Ginés et al. (2004), who found that b^* values were not significantly affected by the albedo concentration in bologna sausages. The white and yellow components in shaddock albedo that give it high values of L^* and b^* could be responsible for this phenomenon. Lightness values increased when albedo was added, indicating a lighter-colored product. It is noteworthy that for albedo concentration > 7.5 %, the lightness ($p<0.05$) was reduced, which was consistent with a study claiming that the emulsified matrix could mask the lightening albedo effect (Fernández-Ginés et al. 2004). It should be noted that the L^* values of frankfurters with 12.5 % added albedo increased greatly ($p<0.05$), indicating that the emulsified matrix could

Fig. 1 Emulsion capacity (EC) of meat batters prepared with different shaddock albedo concentrations. Values marked with * indicate a significant difference between each concentration

Table 3 Effect of shaddock albedo addition treatment on cooking loss and emulsion stability of frankfurters^a

Treatment (%)	Cooking loss (%)	Emulsion stability	
		TEF ^b (%)	PF ^c (%)
0.0	18.43±0.17 ^a	7.67±0.25 ^a	16.50±0.38 ^b
2.5	16.34±0.68 ^c	7.27±0.22 ^b	16.09±0.27 ^{bc}
5.0	14.35±1.05 ^d	6.48±0.19 ^c	15.63±0.20 ^c
7.5	13.32±0.36 ^e	6.27±0.15 ^d	15.66±0.31 ^c
10.0	17.23±0.27 ^b	7.16±0.20 ^b	15.92±0.29 ^{bc}
12.5	13.94±0.46 ^d	7.73±0.20 ^a	16.80±0.37 ^a

^a Different letters in the same column indicate significant differences ($p<0.05$)

^b TEF total expressible fluid

^c PF proportion of fat in total expressible fluid

Table 4 Effect of shaddock albedo concentration treatment on the color characteristics of frankfurters^a

Treatment (%)	L*	a*	b*
0.0	70.92±0.74 ^b	7.94±0.18 ^a	12.80±0.42 ^b
2.5	73.20±0.97 ^a	6.75±0.29 ^c	14.05±0.46 ^a
5.0	72.84±0.89 ^a	6.70±0.27 ^c	14.10±0.51 ^a
7.5	73.26±0.32 ^a	6.80±0.14 ^b	12.90±0.08 ^b
10.0	72.51±0.65 ^a	7.08±0.16 ^b	13.85±0.27 ^a
12.5	73.49±0.58 ^a	7.03±0.07 ^b	13.85±0.11 ^a

^a Different letters in the same column indicate significant differences ($p < 0.05$)

^b L*: lightness; a*: redness; b*: yellowness

mask the lightening albedo effect only within a certain range of albedo concentration.

The presence of shaddock albedo decreased the redness values of cooked frankfurters – this could be expected from the negative a* value of shaddock albedo (i.e. −1.7). There was no significant difference for frankfurters with ≤ 7.5 % concentration of albedo added. With further increase of shaddock albedo, a* values of frankfurters significantly increased ($p < 0.05$). These results were consistent with the work of Aleson-Carbonell et al. (2003) showing that the increasing addition of citrus fiber increased redness in dry-cured sausages, and explained by the presence of antioxidant compounds (Nagy and Attaway 1992) that would inhibit the reduction of myoglobin and nitrosomyoglobin.

There have been many reports that yellowness is the only color parameter not affected by albedo (Aleson-Carbonell et al. 2003; Fernández-López et al. 2004). However, the present study showed that the presence of shaddock albedo increased ($p < 0.05$) the yellowness of cooked frankfurters, except for the samples with 7.5 % concentration of albedo. This phenomenon could be expected, given the high values of b* for shaddock albedo. The decrease of b* values at the 7.5 % albedo

concentration could be the result of having the lowest cooking loss values as well as the more steady meat emulsion masking the yellow compounds present in albedo (Fernández-Ginés et al. 2004).

Texture profile analysis

Shaddock albedo addition resulted in significant differences in the textural properties of frankfurters of hardness, cohesiveness and chewiness, but no significant ($p > 0.05$) changes in adhesiveness and springiness (Table 5). All hardness values were higher for frankfurters with added shaddock albedo than for controls, except for frankfurters formulated with 12.5 % albedo concentration. This could be explained by poor stability of the meat batters formulated with 12.5 % shaddock albedo due to the low pH. Many studies have reported that citrus fiber addition increased the hardness of various meat products (Backers and Noli 1997; Fernández-Ginés et al. 2001, 2004; Thebaudin et al. 1997). Owing to their water-binding ability and swelling properties, insoluble fibers can increase the consistency of meat products through the formation of an insoluble three-dimensional network (Backers and Noli 1997), which can modify rheological properties of the continuous phase of emulsions. Shaddock albedo addition would involve incorporating particles in the protein matrix that would strengthen the binding that occurs during cooking (Viuda-Martos et al. 2010). Except for samples with 12.5 % albedo added, frankfurters incorporating 5 % albedo were the softest, which may be due to the complex results of stability of meat batters and the water and fat retention by shaddock albedo.

There were no significant differences in cohesiveness, until the addition of shaddock albedo reached 10 %. Albedo concentration > 10 % decreased the cohesiveness of frankfurters, and may be due to the particular size of albedo particles causing inconsistency in meat batters. The addition of albedo at any concentration decreased the chewiness of frankfurters compared with controls, which is consistent with the work of Viuda-Martos et al. (2010) and Aleson-Carbonell et al. (2005).

Table 5 Influence of shaddock albedo treatment on the textural attributes of frankfurters^a

Treatment (%)	Hardness (N)	Adhesiveness (N)	Springiness (mm)	Cohesiveness	Chewiness (N×mm)
0.0	24.16±3.24 ^b	0.784±0.251 ^a	3.582±0.004 ^a	0.780±0.012 ^a	89.2±19.5 ^a
2.5	28.69±4.59 ^a	0.755±0.329 ^a	3.581±0.003 ^a	0.775±0.011 ^{ab}	77.8±13.0 ^{ab}
5.0	24.69±4.92 ^b	0.810±0.161 ^a	3.581±0.003 ^a	0.772±0.021 ^{ab}	73.8±11.8 ^b
7.5	26.64±4.30 ^{ab}	0.568±0.175 ^a	3.581±0.003 ^a	0.789±0.013 ^a	86.1±9.9 ^{ab}
10.0	29.01±3.12 ^a	0.636±0.146 ^a	3.580±0.000 ^a	0.771±0.006 ^b	87.4±8.9 ^a
12.5	20.29±3.44 ^c	0.755±0.340 ^a	3.583±0.005 ^a	0.764±0.011 ^b	85.1±10.4 ^{ab}

^a Different letters in the same column indicate significant differences ($p < 0.05$)

Conclusions

The present study demonstrated that shaddock albedo showed potential as a good source of pectin as emulsifier for emulsion-type meat products. The addition of shaddock albedo decreased the cooking loss of frankfurters and enhanced emulsion properties of meat batters. The appropriate range of shaddock albedo utilized in frankfurters was 5.0–7.5 % for the most improvement in cooking properties and overall acceptance.

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