QUALITY CHARACTERISTICS OF REDUCED-FAT VIENNA SAUSAGE USING RICE FLOUR AND SKIM MILK POWDER MIXTURE AS A FAT REPLACER

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Abstract:

The present work investigated the quality characteristics of Vienna sausage containing a mixture of rice flour and skim milk powder (RFSKM) as a fat replacer. Six formulations of Vienna sausage with different amounts of RFSKM (0, 20, 40, 60, 80 and 100%) were produced and evaluated for physicochemical properties and sensory quality. The addition of RFSKM to the sausage significantly increased emulsion stability, viscosity, moisture, and protein content and lowered fat content, calorific value, and cooking loss ($p \leq 0.05$). A rise in RFSKM level led to a significant increase in hardness and chewiness and a reduction of lightness of the sausages. Most sensory likability scores of sausage samples with up to 40% RFSKM were comparable to those of the full-fat control sample. The reduced-fat Vienna sausage with acceptable sensory attributes and lower calories can, therefore, be successfully developed with the incorporation of 40% RFSKM.

Keywords: Vienna sausage; Rice flour; Skim milk powder; Fat replacer

Introduction

Vienna is one of the emulsion-type sausages, which is very popular among Thai people due to its unique flavor and taste. Vienna sausage is a good source of protein. However, it contains high fat and low fiber content. Therefore, frequent consumption of Vienna sausage may thus be associated with obesity, cardiovascular diseases, and arterial hypertension (Olanwanit & Rojanakorn, 2019). Fat, however, provides many gratifying characteristics to Vienna sausages, including upgrading tenderness, juiciness and palatability, reducing cooking loss and stabilizing meat emulsions (Olanwanit & Rojanakorn, 2019). Consequently, a reduction of fat in Vienna sausage formulations may lead to lowered consumer satisfaction. The production of reduced-fat emulsion type sausages with good texture and high sensory acceptability can be performed by using fat replacers (Olanwanit & Rojanakorn, 2019). Fat replacers are compounds that use to give some or all of the functional properties of fat while providing fewer calories than the fat being replaced. They are classified in to 2 groups including fat substitutes and fat mimetics. Fat substitutes are lipid-like substances intended to replace fats on a one-to-one basis whereas fat mimetics are protein or carbohydrate ingredients which function by imitating the physical, textural mouth feel such as juiciness and tenderness, and organoleptic properties of real fats (Shaltout & Youssef, 2007). Fat replacers such as carbohydrate-based materials (Aktaş & Gençcelep, 2006) and protein-based materials (Osburn *et al.*, 1997). In addition, a combination of carbohydrate and protein - *i.e.*, a combination of wheat fiber and pig skin (Choe *et al.*, 2013), a mixture of green banana flour and pork skin (Alves *et al.*, 2016) or a mixture of Man sao powder and hydrolyzed collagen (Olanwanit & Rojanakorn, 2019) was reported to improve the physicochemical and sensory properties of reduced-fat emulsion-type sausages.

Rice flour is one of the most suitable ingredients for many food products due to its hypoallergenic properties, low fat and sodium content, mild flavor and pale appearance (Mancebo *et al.*, 2015). The major components of rice flour are protein and starch, with approximately 8 and 80%, respectively (Hur *et al.*, 2011). It has been reported that starch and protein in rice flour showed high water binding ability (Torbica *et al.*, 2012). Rice flour has the potential to be used in meat industry due to its unique gelatinization properties and water binding capacity. This can retain water during the cooking process and subsequent improve the juiciness, tenderness and mouthfeel of reduced-fat food products (Chun & Yoo, 2004). Therefore, rice flour is one of the potential materials that can be used as a fat replacer. Skim Milk Powder (SMP) is the product resulting from the partial removal of fat and water from pasteurized milk. It is classified as a high protein-low fat content product (Marafon *et al.*, 2011). The major protein in skim milk powder is casein which possesses high water holding capacity and solubility and provides juiciness and tenderness to the food products that it is added (Holt *et al.*, 2013). Therefore, skim milk powder could be used as a fat replacer. However, to our knowledge, studies focusing on the use of rice flour, skim milk powder, and water mixture as a fat replacer in emulsion-type sausages are very limited despite its potential. Therefore, the objective of this study was to determine the effect of incorporating a mixture of rice flour and skim milk powder (RFSKM) as a fat replacer on quality characteristics of Vienna sausage.

Materials and Methods

Preparation of The Rice Flour, Water, And Skim Milk Powder Mixture (RFSKM)

RFSKM was prepared by mixing rice flour, skim milk powder and distilled water in a 2:0.5: 1.35 ratio using a blender. This ratio was based on the findings of a preliminary study. Based on proximate analysis, RFSKM showed 38.56% moisture, 22.84% protein, 0.52% fat and 1.95% ash.

Production of Vienna Sausage

Six formulations of Vienna sausage with different amounts of RFSKM as a fat replacer (0, 20, 40, 60, 80 and 100% by weight) were prepared as per Olanwanit & Rojanakorn (2019) with some modifications. Fresh pork shoulder and pork back-fat used in this study were purchased from the local market in Khon Kaen province. After removing visible fat and connective tissue, the lean meat was ground twice through a 5-mm and 2.5-mm plate, respectively, using a meat grinder (BIRO®, USA). The partially frozen pork back-fat was also ground using the same conditions. The ground pork plus ¼ parts of ice cubes were chopped in a silent cutter (cutter M11N Maschinen, Germany) at high speed for 1 min. Some additives including 1.5% sodium chloride, 0.3% sodium tripolyphosphate, 80 ppm sodium nitrite and ¼ parts of ice cubes were added to the ground pork and chopped at high speed for 2 min. After that 0.1% sodium ascorbate, 1% spices and seasoning, 0.25% monosodium glutamate, and ¼ parts of ice cubes were added to the comminuted meat and further chopped at high speed for 1 min. RFSKM and ground pork fat at test levels, as well as the remaining ice were added to the meat mixture and additionally chopped for 3 min at high speed. The temperature of the raw emulsion or meat batter was maintained below 10±1˚C and monitored with a digital temperature probe (Kane-May, KM330, Harlow, Germany) during sausage preparation. One part of raw batter from each sausage formulation was randomly taken out and stored in the dark at 4±1°C for emulsion stability and viscosity analyses, which were done within 18 h. The other part of the raw batter was stuffed into a 14-mm-diameter plastic casing (LEM products, Canada) using a TWF-12 stuffer (DICK, Germany) and hand-linked at 10-cm intervals. All raw sausage samples were cooked in 80±1°C water bath until the internal temperature reached 72°C. The cooked samples were immediately cooled in an ice bath, vacuum packed, and stored at 4±1°C for one night prior to analyses.

Quality Analyses of The Sausage Samples

The stability of raw emulsion or raw batter was determined as per Colmenero, Ayo, and Carballo (2005). In brief, 20 g of raw batter were filled in pre-weighted plastic tubes (50 mL), centrifuged (5,000 *g*, 30 min at 5°C) and heated at 70±1°C for 30 min in a water bath. The tubes were cooled to 4±1°C. The total amount of fluid separated was collected and expressed as a percentage of sample weight.

The WHC of all raw batter was determined as per Yang *et al.* (2007) with some modifications. Briefly, 15 g of raw batter samples was placed in a 250 mL plastic tube and centrifuged (Sorvall® RC6 Plus, Themo Electron Corporation USA) at 4°C for 20 min at 6,000 g. Then the samples were heated in a water bath at 85°C for 20 min, cooled to room temperature. After cooling, the samples were centrifuged again at 4°C for 20 min at 6,000 *g*. The water released from the samples was separated from the plastic tubes and weighed. The weight of the sample after water separation was also recorded. The WHC was calculated as follows:

$$\text{WHC (\%)} = [1-(BW-AW)/WC] \times 100$$

BW = weight of sample before heating and centrifugation (g)

AW = weight of sample after heating and centrifugation (g)

WC = weight of water content in the sample (g)

A Brookfield viscometer (Model RVT, Brookfield Engineering, USA) with spindle number 7 was used to measure the viscosity of 100 g of the raw batter from each sausage formulation. After 30 s of spindle rotation in the batter sample, a reading was taken (Shand, 2000). The viscosity of the raw batter was expressed as centipoise (cP). The temperature during viscosity measurement for each sample was also recorded (28±1°C).

The cooking loss was determined by weight difference before and after cooking of 5 links of sausages from each sausage formulation in a water bath (80±1°C) until 72°C of core temperature was reached (Andrés, García, Zaritzky, and Califano, 2006).

The proximate composition (moisture, fat, protein, and ash) of all cooked sausage samples was determined as per AOAC procedures (AOAC, 2000). Carbohydrate was calculated by difference method. Total calories (kcal) were calculated for 100 g samples using the Atwater values corresponding to fat (9 kcal g-1), protein (4.02 kcal g-1), and carbohydrates (3.87 kcal g-1) (Luisa García, Cáceres, and Dolores Selgas, 2006).

The color of fresh cut cross-sections from all cooked sausage samples (9 per treatment) was measured using a Hunter colorimeter (Hunter Lab Ultrascan XE, USA) calibrated according to the guideline provided by the instrument supplier and the results were expressed as L* (lightness), a* (redness), and b* (yellowness).

Texture profile analysis (TPA) of the cooked sausages were evaluated using texture analyzer (TA-XT2i, Stable Micro Systems, Surrey, UK) according to the method of Wimontham and Rojanakorn (2016) with slight modifications. Nine cylindrical slices (each 14 mm diameter, 15 mm long) from each sausage formulation were subjected to a two-cycle compression test using a 25 kg load cell. The samples were compressed to 40% of their original length using a 35 mm diameter probe with a cross-head speed of 2.0 mm/s.

Sensory analyses of cooked sausage samples in the laboratory scale were performed using a 9-point hedonic scale test. Thirty untrained panelists who regularly consumed emulsion-type sausages evaluated their likability regarding color, odor, taste, texture, and overall liking (Stone & Sidel, 1993). Before the test, sausage samples were steeped in hot water (95±2°C) in individual pans for 2 min. Two slices (2.5 cm long at 35±1°C) of each sausage formulation coded with 3-digit random numbers were served in random order to the taste panels in individual booths. The taste panelists were instructed to cleanse their palates between samples (Deda *et al.*, 2007).

Design of Experiment and Statistical Analysis

Completely randomized design (CRD) and randomized complete block design (RCBD) were used in this study; the former for chemical and physicochemical attributes, the latter for sensory evaluation. The SPSS for Windows version 23 was used to perform the analysis of variance of the experimental data (ANOVA). The difference among each pair of treatment means at $p \leq 0.05$ was achieved using Duncan's new Multiple Range Test (DMRT). All experiments were carried out in duplicate ($n = 2$), and the results were expressed as means (± SD).

Results and Discussion

Physicochemical characteristics of Vienna sausages

The effect of pork back fat substitution by a mixture of rice flour, water, and skim milk powder (RFSKM) on the physicochemical attributes of Vienna sausages is shown in Table 1-2.

Table 1: Effect of a mixture of rice flour, water and skimmed milk powder on physicochemical properties of the sausage samples

Treatment	L*	a*	b*	Cooking loss (%)	%Total fluid released	Viscosity ($x10^5$ cP)
Control (T0)	64.27±0.49^a	5.73±0.20^a	11.36±0.14^a	4.69±0.21^a	1.55±0.11^a	1.56±0.35^e
T20	63.39±1.23^a	6.15±0.32^a	12.00±0.38^a	3.49±0.03^b	1.32±0.47^b	1.65±0.22^{de}
T40	62.96±1.30^a	5.88±0.25^a	11.49±0.36^a	2.74±0.38^c	1.06±0.57^c	1.72±0.37^d
T60	61.55±1.79^b	5.74±0.68^a	12.11±0.74^a	1.44±0.23^d	0.69±0.61^d	1.89±0.19^c
T80	57.86±1.81^c	5.91±0.41^a	11.78±0.58^a	0.67±0.80^e	0.38±0.10^e	2.23±0.10^b
T100	56.37±1.74^d	5.84±0.54^a	11.74±0.60^a	0.40±0.66^e	0.35±0.15^e	2.54±0.25^a

Means within the same column having different letters were significantly different ($p \leq 0.05$)

The addition of RFSKM significantly influenced the emulsion stability and cooking loss of the sausages ($p \leq 0.05$). The values of total fluid release ranged from 0.35% to 1.55%. An increment of RFSKM led to a reduction of total fluid release, indicating higher emulsion stability. The full-fat control sample (T0) showed the highest values of fluid exudation and thus the lowest emulsion stability ($p \leq 0.05$). This result might be due to the high starch and protein contents of RFSKM, which are able to form a three-dimensional gel network at high temperatures, resulting in higher capture of fat and water within the food matrix (Feiner, 2006). In meat/starch systems, gelatinized starch in RFSKM absorbs more water, but its presence does not cause a chemical interaction between meat proteins and starch because meat protein begins to denature before starches gelatinize (Li &Yeh, 2002; Li & Yeh, 2003). Alamanou *et al.* (1996) explained that the stabilizing effect of starches in emulsions is related to their high electrical charge and having more hydrophilic–lipophilic groups within structure, which increase the lipid and water interactions. These groups form a charged layer round fat droplets, causing mutual repulsion, reducing interfacial tension and preventing coalescence. In addition, the relatively high water absorbing ability of milk protein and its ability to form a network with the muscle protein may improve the stability of raw batter (Youssef & Barbut, 2011). Olanwanit & Rojanakorn (2019) demonstrated that higher emulsion stability was observed when a mixture of Man Sao powder and hydrolyzed collagen was used as a fat replacer in reduced-fat Vienna sausage. Alves *et al.* (2016) reported that an emulsion stability of reduced-fat bologna-type sausage increased with increasing a concentration of pork skin and green banana flour mixture.

The cooking loss of Vienna samples containing various levels of RFSKM ranged from 0.40% to 4.69% (Table 1). An increase in RFSKM level resulted in a reduction of cooking loss ($p \leq 0.05$). The T100 sample (100% RFSKM) showed the lowest cooking loss ($p \leq 0.05$), which could be attributed to having the lowest fluid separation during cooking. Similarly, Olanwanit & Rojanakorn (2019) reported a lower cooking loss when a mixture of Man Sao powder and hydrolyzed collagen was added to Vienna sausage samples as a fat mimetic. Choe *et al.* (2013) also reported that the addition of wheat fiber and pig skin mixture in frankfurter formulations caused a significant reduction of cooking loss.

The viscosity of the raw batter with different levels of RFSKM ranged from 1.56×10^5 cP to 2.54×10^5 cP (Table 1). The incorporation of RFSKM caused a significantly greater batter viscosity ($p \leq 0.05$) as compared to the full fat control sample (no added RFSKM). This result may be due to the high water-holding ability of starch and protein in RFSKM. The highest viscosity was found in the T100 sample, whereas the control (T0) exhibited the lowest viscosity ($p \leq 0.05$). Similarly, Olanwanit & Rojanakorn (2019) reported that the viscosity of raw batter of Vienna sausage increased with increasing concentration of a mixture of Man Sao powder and hydrolyzed collagen as a fat substitute. Choe et al. (2013) also reported that the inclusion of a mixture of wheat fiber and pig skin in frankfurter formulations led to a significant increase in the viscosity of meat emulsion. Shand (2000) included an instant or pre-gelatinized starch in a starch blend as a processing aid to increase the viscosity of the raw batter.

The replacement of up to 40% pork fat with RFSKM did not alter the values of L^*, a^* and b^* of the cooked sausages (Table 1). On the contrary, the sausage samples containing 60% (T60), 80% (T80) and 100% (T100) RFSKM had significantly lower L^* values than the control sample ($p \leq 0.05$). Furthermore, the significant variation of b^* and a^* values among all six samples ($p \leq 0.05$) was not observed (Table 1). Alves *et al.* (2016) demonstrated that the inclusion of a mixture of pork skin and green banana flour as a fat replacer for up to 60% did not modify the L^*, a^*, and b^* values of bologna-type sausages ($p \leq 0.05$). However, the L^* value of the sample containing more than 60% pork skin and green banana flour mixture was lower than the full-fat control sample. The level of pork skin and green banana flour mixture did not change the b^* value of bologna-type sausage ($p \leq 0.05$).

Table 2: Effect of a mixture of rice flour, water and skimmed milk powder on the water holding capacity of the sausage samples

Treatment	**Water holding capacity** (%)
Control (T0)	80.02±0.63[a]
T20	82.79±1.01[b]
T40	85.74±1.21[c]
T60	86.65±0.35[d]
T80	91.04±0.90[e]
T100	91.70±0.99[e]

Means within the same column having different letters were significantly different ($p \leq 0.05$)

As seen in Table 2, the WHC was affected by level of RFSKM ($p<0.05$). The WHC values ranged from 80.02% to 91.70%. The WHC was lowest in the control sample (T0), which showed the highest cooking loss and total fluid released ($p<0.05$). As expected, the WHC increased with increasing RFSK level. This result might be due to the high water retention ability of starch and protein in RFSKM. As stated earlier, in meat/starch systems, gelatinized starch in RFSKM absorbs more water into the polymer matrix, resulting in higher WHC (Li & Yeh, 2002; Li & Yeh, 2003; Aktas & Genccelep, 2006). In addition, the negative charge of casein protein in skim milk powder, a major component of RFSKM can chemically bind with water molecules resulting in a greater water holding ability of sausage samples (Holt *et al.*, 2013). *Yang et al.* (2007) reported that addition of hydrated oatmeal into low-fat sausages improve WHC by decreasing cooking loss. Kim *et al.* (2019) also reported that reduced-fat frankfurter samples with konjac gel showed greater WHC, compared to the full fat sample without konjac gel.

Table 3: Effect of a mixture of rice flour, water and skimmed milk powder on the textural parameters of the sausage samples

Treatment	**Hardness (kgf)**	**Cohesiveness**	**Springiness**	**Chewiness (kgf)**	**Adhesiveness (kgf.sec)**
Control (T0)	3.272±0.479[c]	0.747±0.148[a]	0.987±0.080[a]	2.370±0.233[d]	-0.043±0.002[a]
T20	3.367±0.371[c]	0.735±0.101[a]	0.956±0.259[a]	2.390±0.268[d]	-0.127±0.009[a]
T40	3.410±0.340[c]	0.734±0.008[a]	0.964±0.218[a]	2.402±0.245[cd]	-0.104±0.005[a]
T60	3.638±0.264[c]	0.754±0.453[a]	0.972±0.198[a]	2.628±0.205[c]	-0.007±0.008[a]
T80	4.456±0.246[b]	0.725±0.005[a]	0.972±0.628[a]	3.143±0.229[b]	-0.006±0.006[a]
T100	4.811±0.274[a]	0.774±0.268[a]	0.969±0.463[a]	3.448±0.314[a]	-0.071±0.009[a]

Means within the same column having different letters were significantly different ($p \leq 0.05$)

As seen in Table 3, sausage formulation significantly affected the hardness and chewiness of sausage samples ($p \leq 0.05$). The sample containing 100% RFSKM (T100) exhibited the highest hardness and chewiness whereas the control (T0) showed the lowest value of hardness and chewiness ($p \leq 0.05$). An increase in RFSKM level resulted in a rise of hardness and chewiness of the reduced-fat samples ($p \leq 0.05$). This finding may be observed because the solid content of the sausages may increase with increasing RFSKM, resulting in a harder texture. Surprisingly, an addition of RFSKM as a fat replacer did not affect cohesiveness, springiness and adhesiveness of the sausage samples ($p>0.05$). Olanwanit & Rojanakorn (2019) reported that Vienna sausages containing Man Sao powder and hydrolyzed collagen had higher hardness and chewiness than the control with no Man Sao powder and hydrolyzed collagen addition. Alves *et al.* (2016) also reported that the incorporation of a mixture of pork skin and green banana flour as a fat replacer induced the harder texture to frankfurter-type sausage.

Chemical composition of sausage sample

The result of RFSKM concentration on the chemical composition of Vienna sausages is presented in Table 4.

Table 4: Effect of a mixture of rice flour, water and skimmed milk powder on the chemical composition of the sausage samples

Treatment	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Calorific value (kcal)
control (T0)	59.60±0.67^{e}	12.58±0.09^{e}	16.32±0.63^{a}	2.09±0.38^{a}	233.87±0.87^{a}
T20	61.09±1.96^{d}	13.09±0.06^{d}	13.39±0.61^{b}	2.20±0.00^{a}	212.72±1.02^{b}
T40	63.16±0.62^{cd}	14.04±0.40^{c}	10.18±0.54^{c}	2.25±0.04^{a}	188.19±1.28^{c}
T60	65.57±3.84^{bc}	14.27±0.09^{bc}	6.94± 0.55^{d}	2.39±0.28^{a}	161.62±1.19^{d}
T80	67.58±0.23^{b}	14.50±0.30^{b}	3.31± 0.08^{e}	2.42±0.07^{a}	135.92±0.34^{e}
T100	71.96±2.28^{a}	15.23±0.91^{a}	0.81 ± 0.06^{f}	2.53±0.24^{a}	105.55±0.82^{f}

Means within the same column having different letters were significantly different ($p \leq 0.05$)

An increase in RFSKM concentration resulted in an increase in moisture and protein content of sausage samples, whereas the fat content and energy value decreased ($p \leq 0.05$). Interestingly, the ash content of the samples increased insignificantly with increasing RFSKM level ($p > 0.05$). The moisture content of the control sample (T0) was 59.60%. The values reached 71.96% in the T100 sample, possibly due to the high-water absorption of the starch and protein present in the RFSKM. The fat content of the sausages was the highest (16.32%) in the control and increasing RFSKM level significantly decreased fat contents ($p \leq 0.05$). The addition of 20%, 40%, 60%, 80% and 100% RFSKM showed 17.95%, 36.62%, 57.48%, 79.72% and 95.03% fat reduction as compared to the control, respectively. According to FDA regulation, food products can be claimed as “reduced-fat” if their fat content is reduced to at least 25% of the original fat content (US FDA, 2016). Hence, the Vienna sausage samples with 40% RFSKM or more can be classified as reduced-fat Vienna sausages. As the replacement of pork fat by RFSKM increased, the protein content of the sausage samples increased ($p \leq 0.05$). This may due to the higher protein content of the RFSKM (22.84%) when compared with the pork fat (8.35%). The calorific value of sausage samples greatly depended on the RFSKM level ($p \leq 0.05$) (Table 4). The highest calorific value was found in the control sample (T0) as 233.87 kcal/100 g, whereas the value for sausage samples containing RFSKM ranged from 212.72 to 105.55 kcal/100 g. The calorific value was 9.04% to 54.87% lower in the Vienna samples containing RFSKM as compared to that in the full-fat control sample. Namhong & Rojanakorn (2016) reported that the calorific value of Vienna sausages decreased with increasing concentration of a mixture of sweet potato powder, gelatin powder, and water (in a ratio of 1:0.25:9) as a fat replacer ($p \leq 0.05$). Similarly, Olanwanit & Rojanakorn (2019) indicated that reduced-fat Vienna sausage with a mixture of Man Sao powder and hydrolyzed collagen as a fat replacer possessed lower calorific value as compared to the full fat control.

Sensory evaluation

Sensory likability scores of the sausages were affected by the level of RFSKM (Table 5).

Table 5: Effect of a mixture of rice flour, water and skimmed milk powder on sensory likability scores of the sausage samples

Treatment	Color	Odor	Texture	Taste	Overall liking
control (T0)	6.7±1.4[a]	6.5±1.7[a]	7.5±1.3[a]	7.6±1.2[a]	8.0±0.7[a]
T20	6.4±1.4[a]	6.3±1.5[a]	7.0±1.3[a]	7.1±1.2[a]	7.5±1.0[a]
T40	6.5±1.7[a]	5.8±1.7[a]	7.1±1.5[a]	7.1±1.3[a]	7.4±0.8[a]
T60	6.3+1.6[a]	5.9±1.7[a]	5.3±1.5[b]	5.7±1.3[b]	5.7±1.7[b]
T80	6.4±1.7[a]	5.7±1.6[a]	5.3±1.6[b]	5.3±1.8[b]	5.6±1.9[b]
T100	6.0±1.7[a]	6.0±1.7[a]	5.0±1.7[b]	5.0±1.7[b]	5.1±1.9[b]

Means within the same column having different letters were significantly different ($p \leq 0.05$)

The pork fat replacement with RFSKM did not affect color and odor likability scores of sausage samples ($p>0.05$). However, likability scores of texture, taste, and overall liking depended on sausage formulation ($p \leq 0.05$). The samples with up to 40% RFSKM had all likability scores comparable to the control ($p>0.05$). The samples containing 60%, 80% and 100% RFSKM had lower likability scores for texture, taste, and overall liking than the full-fat control sample (T0) ($p \leq 0.05$), indicating that the incorporation of RFSKM as a fat replacer into the sausage samples at 60% RFSKM or more led to a reduction of some sensory attributes as compared to the control ($p \leq 0.05$). This result may be observed because the panelists could detect the flavor and odor of rice flour and skim milk powder when 60% RFSKM or more were added to the sausage samples. In addition, the texture of these samples was too hard for the panelists to accept. The overall liking scores of the control sample (T0) and the samples with 20% RFSKM (T20) and 40% RFSKM (T40) ranged between 8.0 and 7.4, indicating that the taste panels highly accepted these three samples. Therefore, replacement of up to 40% pork fat by RFSKM can be used to develop acceptable Vienna sausages.

Conclusion

The inclusion of a mixture of rice flour, skim milk powder and water (RFSKM) as a fat replacer in Vienna sausage led to an increase in emulsion stability, batter viscosity, moisture and protein contents, and hardness of the sausage samples. Increasing RFSKM concentration resulted in a reduction of fat content, calorific value, cooking loss, and lightness (L^*) of the sausage samples. The results of sensory evaluation indicated that reduced-fat sausage samples containing up to 40% RFSKM had all sensory likability scores and textural parameters comparable to the full fat control. Therefore, reduced-fat Vienna sausages with high acceptability can be developed by the incorporation of 40% RFSKM as a fat replacer.

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References

Aktaş, N., & Gençcelep, H. (2006). Effect of starch type and its modifications on physicochemical properties of bologna-type sausage produced with sheep tail fat. *Meat Science*, *74*(2), 404–408.

Alamanou, S., Bloukas, J. G., Paneras, E. D., & Doxastakis, G. (1996). Influence of protein isolate from lupin seeds (Lupinus albus ssp. Graecus) on processing and quality characteristics of frankfurters. *Meat Science*, *42*(1), 79–93.

Alves, L. A. A. dos S., Lorenzo, J. M., Gonçalves, C. A. A., Santos, B. A. dos, Heck, R. T., Cichoski, A. J., & Campagnol, P. C. B. (2016). Production of healthier bologna type sausages using pork skin and green banana flour as a fat replacers. *Meat Science*, *121*, 73–78.

Andrés, S. C., García, M. E., Zaritzky, N. E., & Califano, A. N. (2006). Storage stability of low-fat chicken sausages. *Journal of Food Engineering*, *72*(4), 311–319.

AOAC. (2000). Official methods of analysis, 17th ed. Washington *Association of Official*

Choe, J.-H., Kim, H.-Y., Lee, J.-M., Kim, Y.-J., & Kim, C.-J. (2013). Quality of frankfurter-type sausages with added pig skin and wheat fiber mixture as fat replacers. *Meat Science*, *93*(4), 849–854.

Chun, S. Y., & Yoo, B. (2004). Rheological behavior of cooked rice flour dispersions in steady and dynamic shear. *Journal of Food Engineering*, *65*(3), 363–370.

Colmenero, F. J., Ayo, M. J., & Carballo, J. (2005). Physicochemical properties of low sodium frankfurter with added walnut: Effect of transglutaminase combined with caseinate, KCl and dietary fibre as salt replacers. *Meat Science*, *69*(4), 781–788.

Deda, M. S., Bloukas, J. G., & Fista, G. A. (2007). Effect of tomato paste and nitrite level on processing and quality characteristics of frankfurters. *Meat Science*, *76*(3), 501–508.

Feiner, G. (2006). Meat products handbook: Practical science and techonology. Boca Raton:CRC

Food and Drug Administration (FDA). (2016). CFR -21CFR101.62 –

Holt, C., Carver, J. A., Ecroyd, H., & Thorn, D. C. (2013). Invited review: Caseins and the casein micelle: Their biological functions, structures, and behavior in foods. *Journal of Dairy Science*, *96*(10), 6127–6146.

Hur, S., Cho, S., Kum, J.-S., Park, J. W., & Kim, D.-S. (2011). Rice flour—A functional ingredient for premium crabstick. *Food Science and Biotechnology*, *20* (6), 1639–1647.

Kim, D. H., Shin, D. M., Seo, H. G., & Han, S. G. (2019). Effects of konjac gel with vegetable powders as fat replacers in frankfurter-type sausage. *Asian-Australasian Journal of Animal Sciences*, *32*(8), 1195–1204.

Li, J.-Y., & Yeh, A.-I. (2002). Functions of starch in formation of starch/meat composite during heating. *Journal of Texture Studies*, *33*(4), 341–366.

Li, J.-Y., & Yeh, A.-I. (2003). Effects of starch properties on rheological characteristics of starch/meat complexes. *Journal of Food Engineering*, *57*(3), 287–294.

Luisa García, M., Cáceres, E., & Dolores Selgas, M. (2006). Effect of inulin on the textural and sensory properties of mortadella, a Spanish cooked meat product. *International Journal of Food Science and Technology*, *41*(10), 1207–1215.

Mancebo, C. M., Merino, C., Martínez, M. M., & Gómez, M. (2015). Mixture design of rice flour, maize starch and wheat starch for optimization of gluten free bread quality. *Journal of Food Science and Technology*, *52*(10), 6323–6333.

Marafon, A. P., Sumi, A., Alcântara, M. R., Tamime, A. Y., & Nogueira de Oliveira, M. (2011). Optimization of the rheological properties of probiotic yoghurts supplemented with milk proteins. *LWT - Food Science and Technology*, *44* (2), 511–519.

Namhong, S., & Rojanakorn, T. (2016). *Quality Evaluation of Vienna Sausage Incorporated with Sweet Potato Flour and Gelatin Mixture as a Fat Replacer*. 9. *In 3rd International Postgraduate Symposium on Food and Biotechnology* (IPSFAB2016). Thailand: Maha Sarakham University.

Olanwanit, W,. & Rojanakorn, T. (2019). Effect of hydrolysed collagen and *Man-sao* powder mixture as a fat replacer on quality of Vienna sausages. *International Food Research Journal, 26(5), 1525-1523.*

Osburn, W. N., Mandigo, R. W., & Eskridge, K. M. (1997). Pork Skin Connective Tissue Gel Utilization in Reduced-Fat Bologna. *Journal of Food Science*, *62*(6), 1176–1182.

Shaltout, E. (2007). *Fat Replacers and Their Applications in Food Products: A Review*. *4*, 16.

Shand, P. J. (2000). Textural, Water Holding, and Sensory Properties of Low-fat Pork Bologna with Normal or Waxy Starch Hull-less Barley. *Journal of Food Science*, *65*(1), 101–107.

Shand, P. J. (2000). Textural, Water Holding, and Sensory Properties of Low-fat Pork Bologna with Normal or Waxy Starch Hull-less Barley. *Journal of Food Science*, *65*(1), 101–107.

Stone, H and Sidel, J. L. (1993). Sensory evaluation practices. 2nd ed. Academic Press, Inc. New York.

Torbica, A., Hadnađev, M., & Dapčević Hadnađev, T. (2012). Rice and buckwheat flour characterisation and its relation to cookie quality. *Food Research International*, *4* (1), 277–283.

Wimontham, T,. & Rojanakorn, T. (2016). Effect of incorporation of Gac *(Momordica cochinchinensis)* aril powder on the qualities of reduced-nitrite Vienna sausage. *International Food Research Journal 23 (3): 1048-1055.*

Youssef, M. K., & Barbut, S. (2011). Effects of two types of soy protein isolates, native and preheated whey protein isolates on emulsified meat batters prepared at different protein levels. *Meat Science*, *87*(1), 54–60.