Characteristics of Reduced-Fat Thai Pork Sausage with Inulin Addition

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***Abstract*—The aim of this study was to evaluate the effect of different concentration of inulin as fat replacers on the chemical composition, physical properties, textural characteristics, and sensory acceptance of Thai style pork sausages. Six batches were prepared with added inulin from 0-60 % of fat content. The results showed that the addition of inulin increased moisture and fiber content while decreased fat content of the sausages. Color parameters and cooking yield were not significantly different, while the water activity were slightly increased. Cooking times were also reduced. Texture properties; hardness, cohesiveness, springiness, gumminess, and chewiness of inulin added sausages were slightly lower than those of the control sausages. The addition of inulin improved the sensory properties of reduced fat pork sausages. The sausages with 30 % of inulin replaced was the most acceptable due to their highest scores in all sensory attributes. Therefore, inulin can be used as a fat replacer in Thai pork sausage to obtain healthy and functional product.**

***Index Terms*—inulin, reduce-fat, physical properties, acceptance, Thai pork sausage**

I. Introduction

Fat is an important source of energy and essential fatty acids as well as carrier of fat soluble vitamins in meat products [1]. In addition, fat plays an important role in stabilization of meat emulsions, reduction of cooking loss, improving texture, tenderness, juiciness and mouth feel [2]. However, food consumption habits are changing due to the awareness of obesity and cardiovascular diseases and these changes has driven the development of healthier meat products with functional ingredients [3]. Many procedures have been focused on reducing fat content in meat products while maintaining product acceptance without affecting its appearance, smell and flavor. However, these procedures should also pay attention to the nutritional factors, the safety of the products, technological and/or processability factors, general regulation, general consumer appreciation, legal regulations as well as the costs of the products [4].The dietary fibers provide technological functions such as water binding capacity which can reduce shrinkage, cooking loss, drip loss during storage and minimize production costs without affecting sensory attributes [5].

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Inulin is an oligo-fructose polymer of interest in human nutrition due to its ability to act as dietary fiber with low caloric value and health related benefits [6], [7] and prebiotics which stimulate the immune system of the body by promoting the growth of fecal bifidobacteria (beneficial gut flora) [8], [9]. Inulin has been increasingly used as fat and sugar replacer in processed functional foods [10]. Inulin can be used as a fat replacer in food products because it can form a gel with water and the resulting gel has a texture that gives a creamy and juicy mouthfeel in low fat product [11]. Thai pork sausage or Moo-Yor is a traditional ready to eat cooked sausages in Thailand which is popular among consumers in all regions of Thailand and some Southeast Asian countries since it is convenient for consumer to buy and it can also be served in many different dishes. Moo-Yor is cooked sausages mainly consisting of pork meat, pork back fat, salt, and spices. Effect of addition of inulin in Chinese style sausage [12] and in frankfurter sausage [13] had been studied, and the results revealed that inulin was acceptable to be used as fat replacer. However, the formulations of these kinds of sausage are different from that of Thai pork sausage. Therefore, the aim of this study was to evaluate the effect of inulin as fat replacer on the chemical composition, physical properties, textural characteristics and sensory acceptance of Thai pork sausage.

II. Materials and Methods

A. Raw Materials

Fresh pork leg meat and pork back fat were purchased from a local butcher shop in Bangkok, Thailand on the day of experiment. Salt, sugar, pepper, flour and ground ice were purchased from a local super market (Top Supermarket, Bangkok). Mixed polyphosphate was purchased from Food Equipment, Co., Ltd. and commercial inulin powder (90% purity) was supplied by Jebsen & Jessen Technology (T) Ltd. (Thailand).

B. Manufacture of Thai Pork Sausage

The sausages were prepared according to a traditional formula for Thai style sausage. The adjusted formulations used in the manufacture of the control, the different pork sausage batches containing five different fat replacing level of inulin (20%, 30%, 40%, 50%, and 60%) are shown in Table I. The formulations containing inulin, fat was replaced by inulin in aqueous form which was

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prepared by dissolving 10 g of inulin powder in 20 ml of hot boiling water and then was adjusted to 200 ml solution in accordance to U.S. Pharmacopeia [14]. All fat and connective tissues were removed from the muscles of pork leg meat. The lean meat and fat were separately ground through a 2 mm plate grinder and were packaged in the plastic bags and stored at -20˚C for use within 24 h. The frozen ground meat and fat were then chopped with salt, ice, flour, seasonings, polyphosphate, and inulin solution until it turns into pork emulsion. Each portion (250g) of pork emulsion was packed in a high density polyethylene bag and then was cooked by steaming until the internal temperature reached 72˚C. Then, the sausages were cooled down in ice water (10 ˚C) and kept in the refrigerator for further chemical, physical, textural and sensory analyses [15].

TABLE I. FORMULATIONS OF PORK SAUSAGES ADDED WITH DIFFERENT LEVELS OF INULIN

Ingredient (%)	Fat replacement with inulin (%)					
	0	20	30	40	50	60
Lean meat	61.1	61.1	61.1	61.1	61.1	61.1
Fat	12.2	9.8	8.6	7.4	6.1	4.8
Inulin	0	2.4	3.6	4.8	6.1	7.4
Ice	18.8	18.8	18.8	18.8	18.8	18.8
Pepper	1.4	1.4	1.4	1.4	1.4	1.4
Salt	1.4	1.4	1.4	1.4	1.4	1.4
Sugar	2.0	2.0	2.0	2.0	2.0	2.0
Flour	3.0	3.0	3.0	3.0	3.0	3.0
Phosphate	0.12	0.12	0.12	0.12	0.12	0.12

C. Chemical Composition

Moisture, fat, crude fiber, and protein content of the cooked sausage samples were determined according to the methods of AOAC [16]. Moisture content was determined by drying in an oven at 105˚C 2 hr. Fat content was determined using the Soxhlet method with solvent extraction system (Soxtec Avanti 2050, Foss Tecator, Denmark). Protein content was determined using Kjeldahl method (Kjeltec 2300 Analyzer, Foss Tecator, Denmark). Fiber content was determined using a fiber analyzer (Fibertec 8000, Foss, Denmark).

D. Physical Analyses

Water activity of the cooked sausages were measured after equilibrium at 25˚C using a water activity meter (Aqua Lab 4, USA).

The color of the cooked sausages were measured using a spectrophotometer (Hunter Lab, Color Quest XE, USA) equipped with a light source illuminant D65 and 10-degree standard observer. CIELAB system: L*(lightness), a* (redness) and b* (yellowness) values were measured.

Cooking yield of the cooked sausages were measured after pork sausages were cooked by steaming until the internal temperature reached 72˚C and cooled down in ice water. The cooking yield was measured by calculating weight differences of sausages before and after cooking using the following formula [17]:

$$\text{Cooking yield (\%)} = \frac{\text{Cooked weight}}{\text{Uncooked weight}} \times 100$$

E. Cooking Time

Changes in temperature during cooking were monitored using a time temperature data logger (Xplorer GLX-PS-2002) equipped with thermocouples type K (PS2125, Pasco Scientific, USA) to obtain the cooking time of the sausage when the internal temperature of the sausages reach 72˚C. Each thermocouple was inserted through a layer of plastic bag to the geometrical center of the sausage during cooking. The cooking time was the time used to heat the sausage from 20˚C to 72˚C.

F. Texture Profile Analysis

The texture profile analysis of the cooked sausage were analyzed using a texture analyzer (Lloyd instrument, TA plus, UK) equipped with 0.1 kN load cell and a ball probe (1.2 cm diameter). Five sample pieces (2cm width×2 cm length×2.5 cm height) from each of the cooked sausage were prepared and compressed to 50% of its initial height at a cross head speed of 200 mm/min to obtain the texture profile analysis indices: hardness (N), cohesiveness, gumminess (N), springiness (mm) and chewiness (Kgf) [18].

G. Sensory Evaluation

The sensory analysis of sausages were evaluated by 30 untrained faculty members of Suan Sunandha Rajabhat University. The sausage was cut into slices of 5 mm thick and served to the assessors. A 9 point hedonic scale (9=like extremely and 1=dislike extremely) was used to determine different attributes: appearance, color, flavor, taste, texture and overall acceptability [19].

H. Statistical Analysis

All experiments and analytical measurements were conducted in triplicate. Analysis of variance was performed on all variables assessed. Duncan's multiple range test was used to determine the difference among treatment means. A value of $p<0.05$ was used to indicate significant difference.

III. RESULTS AND DISCUSSION

A. Chemical Composition of Pork Sausages

Table II shows the chemical composition of sausages with different levels of inulin replaced (0-60% of fat). Significant effects ($p<0.05$) were found in moisture, fat, and fiber contents, but there were no differences in the protein content. The addition of dissolved inulin solution increase moisture content in the sausages. Fat level was highest in control sample because it was formulated with the highest content of back fat (12.2%), while other treatments had lower fat content because of the increasing of fat replacement with inulin. The use of inulin in sausages effectively reduces the fat content of products

and their energy value which is beneficial for consumer health [20]. On the other hand, the significant increase in fiber content was found when fat was increasingly replaced with inulin. The replacement of inulin at 60 % of fat resulted in products with a 57.6 % lower fat content and a 91.7% higher fiber content. The similar changes were found in the composition of reduced fat frankfurter sausages using inulin and pectin [13].

TABLE II. CHEMICAL COMPOSITION OF PORK SAUSAGES ADDED WITH DIFFERENT LEVELS OF INULIN

Chemical Composition (%)	Fat replacement with inulin (%)					
	0	20	30	40	50	60
Moisture	63.21 ±0.35^{e}	64.42 ±0.32^{d}	66.47 ±0.44^{c}	68.15 ±0.27^{b}	69.22 ±0.48^{b}	70.41 ±1.95^{a}
Fat	10.08 ±0.31^{a}	8.354 ±0.24^{b}	7.44 ±0.28^{c}	9.73 ±0.25^{d}	5.55 ±0.34^{e}	4.27 ±0.44^{f}
Protein ^{ns}	14.01 ±0.24	14.05 ±0.38	14.16 ±0.28	14.01 ±0.44	13.97 ±0.18	14.16 ±0.24
Fiber	0.36 ±0.14^{f}	0.47 ±0.04^{e}	0.52 ±0.17^{d}	0.57 ±0.08^{c}	0.63 ±0.15^{b}	0.69 ±0.16^{a}

Mean ± standard deviation in the same row with different letters are significantly different ($p<0.05$)
ns= no significant difference ($p<0.05$)

TABLE III. COLOR, WATER ACTIVITY, COOKING YIELD, AND COOKING TIME OF PORK SAUSAGES ADDED WITH DIFFERENT LEVELS OF INULIN

Parameter	Fat replacement with inulin (%)					
	0	20	30	40	50	60
L*^{ns}	69.66 ±1.90	69.88 ±1.92	70.52 ±0.71	70.52 ±0.44	69.86 ±0.91	70.04 ±1.04
a*^{ns}	2.08 ±0.32	2.29 ±0.18	2.27 ±0.26	2.35 ±0.20	2.23 ±0.06	2.12 ±0.34
b*	12.79 ±1.06^{a}	12.12 ±0.24^{ab}	12.03 ±0.48^{ab}	12.11 ±0.62^{ab}	11.98 ±0.82^{b}	11.74 ±0.56^{b}
Water Activity	0.96 ±0.00^{c}	0.97 ±0.00^{b}	0.97 ±0.01^{b}	0.97 ±0.00^{b}	0.98 ±0.00^{a}	0.98 ±0.01^{a}
Cooking yield (%)^{ns}	98.45 ±0.20	98.35 ±0.40	98.35 ±0.28	98.65 ±0.34	98.23 ±0.28	98.14 ±0.20
Cooking Time (min)	12.5 ±0.25^{a}	8.0 ±0.75^{b}	7.75 ±0.50^{c}	7.5 ±0.25^{d}	7.25 ±0.50^{e}	7.0 ±0.25^{f}

Mean ± standard deviation in the same row with different letters are significantly different ($p<0.05$)
ns= no significant difference ($p<0.05$)

B. Physical Properties of Pork Sausages with Inulin

The effect of replacing back fat with different levels of inulin on color, water activity, cooking yield, and cooking time of sausages are presented in Table III. The L* value and a*value of the various groups were not significantly different, indicating that the introduction of inulin does not significantly influence the color of sausages.

The addition of inulin significantly affected the water activity of sausages because inulin were used in soluble in water. This high water activity level (>0.9) could allow the sausage to be easily spoiled by microorganisms.

Cooking yield of the sausages were not significantly different among all formula. The results indicated that inulin has high water and fat holding capacity during manufacturing process since it is responsible for the appearance and juiciness of meat products and good quality meat products should have a cooking loss below 10 % [21]. In our study, the sausages showed a good cooking yield which varied from 98.14% to 98.65 %.

The cooking time swiftly decreased when fat was increasingly replaced with inulin solution since thermal conductivity or thermal transfer rate in a meat emulsion increases with process temperature and moisture content [22]. Introducing inulin to replace fat in sausage could reduce cooking time and cost of energy as well.

C. Texture Characteristics of Pork Sausages with Inulin

TABLE IV. TEXTURE PROFILE ANALYSIS OF PORK SAUSAGES ADDED WITH DIFFERENT LEVELS OF INULIN

Texture Profile Index	Fat replacement with inulin (%)					
	0	20	30	40	50	60
Hardness (N)	31.26 ±2.20^{a}	26.87 ±1.65^{b}	25.54 ±1.86^{c}	25.38 ±2.30^{c}	23.20 ±2.27^{d}	22.09 ±1.86^{e}
Cohesiveness	0.63 ±0.01^{a}	0.63 ±0.02^{a}	0.62 ±0.02^{b}	0.60 ±0.03^{c}	0.53 ±0.05^{d}	0.53 ±0.04^{d}
Springiness (mm)	6.48 ±0.34^{a}	6.41 ±0.28^{a}	6.59 ±0.34^{a}	5.64 ±0.46^{b}	5.75 ±0.58^{b}	5.18 ±0.70^{c}
Gumminess (N)	1.71 ±0.24^{a}	1.61 ±0.24^{b}	1.64 ±0.30^{b}	1.54 ±0.24^{c}	1.41 ±0.30^{d}	1.41 ±0.40^{d}
Chewiness (kgf)	13.42 ±0.28^{a}	13.11 ±0.47^{a}	10.87 ±0.40^{b}	10.66 ±0.62^{b}	8.87 ±0.70^{s}	7.85 ±0.80^{d}

Mean ± standard deviation in the same row with different letters are significantly different ($p<0.05$)

The results of texture profile analysis after introducing different levels of inulin to sausages are presented in Table IV. Hardness, cohesiveness, springiness, gumminess, and chewiness values were lower in sausages with inulin fiber compared to control sausages ($p<0.05$). The findings indicated that the textural qualities of the sausages were deteriorated when the fat content was reduced and the water content was increased which were

agreed to [23]. In this study, the sausages with inulin fibers were softer than the control samples since hardness could be affected by the fat content and the dietary ingredients due to their high binding ability and water holding capacity [24], [25] and the results are in agreement with the previous finding which revealed that the incorporation of inulin in a gel form made the sausage softer [26]. An effect of inulin on the springiness of the sausages was observed when replacing levels of inulin were greater than 30 % of fat.

TABLE V. SENSORY EVALUATION OF PORK SAUSAGES ADDED WITH DIFFERENT LEVELS OF INULIN

Sensory Attributes	Fat replacement with inulin (%)					
	0	20	30	40	50	60
Appearance	6.47 ± 0.60^{bc}	7.07 ± 0.54^{ab}	7.43 ± 0.65^{a}	7.03 ± 0.42^{ab}	$6.60 \pm^{b}$	5.80 ± 0.70^{c}
Color	6.60 ± 0.54^{ab}	6.87 ± 0.50^{ab}	7.20 ± 0.67^{ab}	7.43 ± 0.60^{a}	6.63 ± 0.54^{ab}	6.43 ± 0.56^{b}
Odor	6.10 ± 0.60^{b}	6.93 ± 0.60^{a}	7.20 ± 0.48^{a}	6.60 ± 0.53^{ab}	5.87 ± 0.50^{b}	5.97 ± 0.60^{b}
Flavor	6.47 ± 0.60^{c}	7.47 ± 0.60^{ab}	7.77 ± 0.64^{a}	6.77 ± 0.53^{bc}	5.97 ± 0.60^{cd}	5.70 ± 0.64^{d}
Texture	5.87 ± 0.70^{d}	7.17 ± 0.34^{ab}	7.77 ± 0.60^{a}	6.63 ± 0.54^{bc}	6.10 ± 0.80^{cd}	5.10 ± 0.40^{e}
Overall Acceptability	6.63 ± 0.62^{cd}	7.40 ± 0.64^{ab}	8.00 ± 0.50^{a}	7.23 ± 0.74^{bc}	6.40 ± 0.68^{de}	5.77 ± 0.40^{e}

Mean ± standard deviation in the same row with different letters are significantly different ($p<0.05$)

D. Sensory Evaluation of Pork Sausages

Table V presents the results of evaluation of acceptance for the sausages. The addition of inulin affects the sensory attributes ($p<0.05$). The sausages with 30 % inulin replaced were the most acceptable due to their highest appearance, odor, flavor, texture, and overall acceptability scores, while the sausage with 60% inulin replaced was the least satisfactory. Texture of the reduced fat sausages at 30% inulin addition gained the highest acceptability from assessors due to their less hardness, cohesiveness, gumminess and chewiness compared to the control samples (Table IV). In this study, replacing fat with inulin at a suitable level could improve better acceptance for the sausages. Similar results was found in the addition of inulin on the sensory properties of Chinese style sausages which suggested that the high solubility of inulin could improve textural properties [8]. However, the sensory scores of sausages with 40% and 50% inulin replaced were not significantly different from those of the control samples. Therefore, production of sausages with inulin addition up to 50 % of fat could be possible and could resulted in products with a 45 % lower fat content and a 75% higher fiber content compared to the control sausages (Table II).

IV. CONCLUSION

The incorporation of inulin as a fat substitute increased the fiber content, moisture content and reduced the fat content, but not affected the color and cooking yield of the sausages. Production cost could be reduced due to less cooking time. The sensory attributes were improved through the significant changes of the texture properties. The sausages with 30 % of inulin replaced was the most satisfactory (8.0) due to their highest scores in all sensory attributes. Inulin can be added up to 50% of fat content in the sausages to obtain a 45 % lower fat content and a 75% higher fiber content products with no significant difference in sensory properties compared to the control sausages. Therefore, in formulating of reduced fat Thai pork sausages, inulin can be used as a fat replacer to reduce calories and increase prebiotic ingredient for better consumer health.

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