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Research

Effects of Different Types of Starches on Katjang Goat Meat Emulsion Characteristics

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ABSTRACT

Katjang goat meat has the potential to be used for emulsified meat product production but the suitable starch type to be applied as the filler is unknown. The present study was undertaken to evaluate the effect of various starches on the quality characteristic of Katjang goat meat emulsion. Katjang goat meat emulsion was prepared by incorporating various starches viz., tapioca starch (TS), sago starch (SS), and wheat starch (WS), as filler by replacing lean meat. The developed emulsion samples were evaluated for physiochemical, proximate, colour, texture, and gel strength. The addition of TS into meat emulsion results in the most stable emulsion as exhibited by the lowest total expressible fluid (%TEF), expressible fat (%EFAT), and cooking loss. There was no significant (p>0.05) difference for the pH, water holding capacity (WHC), texture profile analysis (TPA), and colour values of all the samples. The incorporation of SS in the formulation decreased (p<0.05) the shear force and work of shearing. In conclusion, the incorporation of TS was found optimum to formulate goat meat emulsion with better quality characteristics.

Key words: Cooking loss, Katjang goat, meat emulsion, quality attributes, starch, water holding capacity

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INTRODUCTION

Katjang goats also known as Kambing Kacang, Kambing Katchang, Kambing Licin, and Pea Goats are native to Malaysia and Indonesia, and also commonly found throughout Southeast Asia such as the Philippines and Thailand (Muneerah *et. al*., 2021). Although Katjang goats are smaller in size (approximately 45-60 cm in height & 60-80 cm in length) compared with other imported breeds of goats such as Boer, Saanen, and Jamnapari, Katjang goat has the advantage of being able to withstand hot and humid tropical environment around the year and resist towards parasites infestation (Bakar *et. al*., 2018). Goat meat is generally a healthier choice for meat consumption as they are lower in cholesterol compared to other meats (Ismail *et. al*., 2021a). However, despite being one of the essential livestock industries for the agriculture sector in Malaysia and high in demand, the ruminant sub-sector in Malaysia is still small and does not meet the demand for goat meat and meat products (Rosali & Nor, 2015).

Meat and meat products are important sources in human diets due to the abundance of nutrients such as protein, zinc, iron, vitamin, cholesterol, and fats (Anzani *et. al*., 2020; Asyrul-Izhar *et al*., 2023a). In the meantime, those nutrients can also be considered an excellent growth medium for various microorganisms that cause spoilage. To minimize the risk of spoilage and increase shelf life and eating quality, meat is usually processed into meat products such as meatballs, sausages, and patties. Manufacturing processed meat products consists of a vital process called meat mixing and emulsification (Asyrul-Izhar *et al*., 2021; Kim *et al*., 2021). A meat emulsion is a combination of two physically distinct phases, including a disperse phase made up of fat globules and a continuous phase of a gel-like medium made up of a matrix of water, soluble myofibrillar proteins, salts, phosphates, and other non-meat substances (Ismail *et al*., 2021a).

Starches as filler are added to meat emulsion products for their low-cost price and their well-known functional properties. Starch is widely used in the food industry as a thickener, emulsifier, stabilizer, and gelling agent (Kaur & Sharma, 2019; Asyrul-Izhar *et al*., 2023b). Starches from tapioca starch (*Manihot esculenta*), sago starch (*Metroxylon sagu*), and wheat flour (*Triticum aestivum L.*) are among starch from plant sources that are commercially used in the food industry. Starch is composed of amylopectin and amylose. Amylopectin is highly branched, with the branch point at a-(1,6) bonds. Amylose is essentially a linear long-chained a-(1,4) linked glucose molecule with some minor branching a-(1,6) branch points (Bao, 2019). Each starch has a different amylose/amylopectin ratio and the processing condition of the starch will determine the functional properties depending upon the ability of starch to gelatinize during thermal processing consequently binding and retaining fluids (Mahmood *et al*., 2017). It resulted in improving the functional attributes of meat emulsion such as water holding capacity (WHC), texture profile, nutritive quality, and organoleptic properties. The incorporation of starch in meat emulsion was observed to improve emulsion stability such as rice flour and tapioca starch in pork sausage emulsion (Pereira *et al*., 2019), corn starch and wheat flour in various meat emulsion (Correia & Mittal, 2000), potato starch in beef emulsion (Genccelep *et al*., 2015), etc.

Studies on the effect of various starchs on Katjang goat meat emulsion are lacking. There is a need to evaluate the effect of the incorporation of commonly available starch on the quality attributes of Katjang goat meat emulsion; thereby developing good quality Katjang goat meat products. Thus, the present work evaluated the effect of different types of starches, which are tapioca starch, sago starch, and wheat starch, on the physicochemical properties of the Katjang goat meat emulsion system. Further, the present work also evaluated the effect of stated starches incorporated could reduce the meat percentage during the formulation of a stable Katjang goat meat emulsion system.

MATERIALS AND METHODS

Materials

Katjang goat meat and fat were purchased from a local butcher (RB Meat Sdn Bhd) in Seri Kembangan wet market (Selangor, Malaysia). The tapioca starch (Cap Kapal ABC), sago starch (Cap Bintang), and wheat starch (Cap Bintang) were purchased from the local market. Meat emulsions with four different formulations viz., tapioca starch (TS), sago starch (SS), and wheat starch (WS) were produced as per Table 1. The starch addition was selected at a 10% level for each type of starch by replacing lean meat based on preliminary trials and available literature. First, the required amount of meat and fat was thawed and ground using a meat mincer (Guangzhou Panyu Hanglin Food Processing Machine Factory, China). Then, the required amount of meat was mixed with fat and ice water (50% of the total) for 60 s using a food processor (Food Processor Gourmet Cuisine, China). Further, salt and sodium tripolyphosphate (STPP) were added and mixed for 30 s. The ice water (remaining 50%) was added and mixed for 30 s and the developed emulsion was transferred into a centrifuge tube. The meat emulsion was centrifuged at 2500 rpm at 3°C for 60 s to eliminate air bubbles and stored in a freezer until further use.

Table 1. Formulation of Katjang meat emulsion

Ingredient (%)	Control	TS	SS	WS
Meat	80	70	70	70
Fat	10	10	10	10
Tapioca starch	0	10	0	0
Sago starch	0	0	10	0
Wheat starch	0	0	0	10
Salt	1.2	1.2	1.2	1.2
STPP	0.3	0.3	0.3	0.3
Ice water	8.5	8.5	8.5	8.5

Note: TS; tapioca starch, SS; sago starch, WS; wheat starch, STPP-sodium tripolyphosphate

Emulsion stability

The emulsion stability was determined according to Öztürk-Kerimoğlu (2021) with slight modifications. Briefly, 10 g of each raw sample was stuffed into a centrifuge tube and centrifuged at 3000 × *g* at 4°C for 15 min. The samples were heated in a water bath at 75°C for 30 min. The tube cap was removed and the tube was left upside down for 60 min to dry the expressible fluid in a crucible. The remaining pellet in the tube was weighed and oven-dried the remaining fluid was in the crucible using a drying oven (Binder, Germany) at 105°C for 16 hr. After drying, the remaining fluid in the crucible was determined as the total fat release, and the weight of the crucible with the remaining fluid left was measured. The volume of total expressible fluid (%TEF) and expressible fat (%EFAT) were calculated using the following Equation 1 and Equation 2.

Equation 1:

$$TEF(\%)=\frac{(\text{Centrifuge tube weight}+\text{Sample weight}) - (\text{Centrifuge tube weight} + \text{Pellet weight})}{\text{weight of sample}} \times 100$$

Equation 2:

$$EFAT(\%)=\frac{(\text{Weight of crucible} + \text{Weight of dried supernatant})-(\text{Weight of empty crucible})}{\text{Total expressive fluid}} \times 100$$

pH

The pH of each meat emulsion was measured using a pH meter (Jenway 3505 pH meter, United Kingdom) following the method by Ismail *et al*. (2021a) with slight modifications. For raw samples, a 5 g sample and 45 mL of distilled water were mixed using a blender (Panasonic MX-898M, Malaysia) for 60 s, and pH was measured. Meanwhile, for the cooked samples, each sample was cooked in a water bath (Memmert, WNB 7, Germany) at 90°C for 15 min. The cooked samples were tempered at room temperature for 30 min and 5 g of the cooked samples were homogenized with 45 mL of distilled water for 60 s before the pH value of the cooked samples was measured.

Cooking loss

The cooking loss was measured by the following procedure described by Ismail *et al*. (2021a) with slight modifications. A 5 g sample was placed into a centrifuge (Kubota 3470, Japan) at 1000 rpm for 60 s to remove air bubbles. The sample was then immersed in the pre-heated water bath at 80°C until the internal temperature reached 72°C, measured using a thermocouple. The sample was cooled in an ice-water bath for 5 min. The pelleted sample was weighed and cooking loss was calculated by the following Equation 3.

$$\text{Cooking Loss } (\%)=\frac{(\text{weight of the uncooked sample} - \text{the weight of the pellet})}{\text{weight of the uncooked sample}} \times 100$$

Water holding capacity (WHC)

WHC of the developed emulsion was assessed by following the method as per Bowker (2017) with slight modifications. Five g of the raw sample was mixed with 32 mL of distilled water for 60 s. After that, the samples were left for 10 min and centrifuged at 2900 × *g* for 25 min. The supernatant was weighed with the centrifuge tube and discarded. After that, the remaining pellet was dried downward at 50°C for 20 min and the dried pellet was weighed. Water holding capacity was calculated using the following Equation 4.

$$WHC=\frac{(b-a)-(c-a)}{(b-a)} \times 100$$

Which,

a = weight of empty centrifuge
b = weight of centrifuge with supernatant
c = weight of dried centrifuge

Proximate analysis

The proximate composition of meat emulsion samples was determined as per the standard procedures of the Association of Official Analytical Chemists (AOAC, 1995). The moisture (oven drying at 105°C to constant weight), fat (Soxhlet extraction by using petroleum ether as solvent), protein (Kjeldahl distillation, N× 6.25), crude ash (muffle furnace, at 550°C for 24 hr) contents were estimated and carbohydrate content, by calculation.

Color

The colors (CIE L*, a*, & b*) of the raw and cooked samples were measured using a chroma meter CR-410 (Konica Minolta, Japan). The raw samples were thawed in capped centrifuge tubes using running water for 30 min at room temperature before conducting color measurements. This step was taken to guarantee a complete defrosting of the samples. Following the cooking process, the samples were allowed to cool at ambient temperature for 30 min before the evaluation of their color. The lightness (L*), redness (a*), and yellowness (b*) were recorded at 8 mm aperture size, D65 illuminant at 2° standard. The equipment was calibrated by using white tiles supplied with the equipment (Ming-Min & Ismail-Fitry, 2023).

Texture profile analysis (TPA)

Samples were cooked in a water bath (Memmert, Germany) at 90°C for 15 min. The samples were tempered at room temperature, and cut into a cylindrical shape with a core of 10 mm length × 20 mm diameter and analyzed using a texture analyzer (TA-XT2i, United Kingdom) twice using a probe (T-75) at a pre-speed test of 1 mm/s, test speed of 1.5 mm/s, post speed test at 1.5 mm/s, and pushing height of 75%. The parameters measured were hardness, adhesiveness, cohesiveness, gumminess, chewiness, and resilience (Ismail *et al*., 2021b).

Shear force and work of shear

The gel shear force and work of shear of meat emulsion were determined using the method by Ismail *et al*. (2021b) using Texture analyzer TA-XT2i (Stable Micro System, United Kingdom). The maximum shear force (N) and work of shearing (N. sec) were measured with 25 kg of load. The sample of 2.5 cm × 2 cm was cut using a Warner-Bratzler (WB) shear blade with a triangle slow cutting edge (1 mm of thickness) at the cut speed of 1.5 mm/s.

Statistical analysis

The analysis was done in triplicate for each starch. The data were analyzed using the Statistical software Minitab 19 (Minitab Inc., U.S.A). One-way analysis of variance (ANOVA) was carried out to compare the samples with a significant level of 95% ($p<0.05$). The data were presented as mean ± standard deviation.

RESULTS AND DISCUSSION

Emulsion stability, pH, cooking loss, and water holding capacity (WHC)

The total expressible fluid (% TEF) was recorded significantly ($p<0.05$) lower in Katjang goat meat emulsion prepared by incorporating TS, and WS; whereas the SS sample was not significant ($p>0.05$) compared to the control (Table 2). TS samples recorded the lowest % EFAT among all treatment and control samples. The incorporation of various starches ie., TS, SS, and WS had effects on the emulsion stability of the Katjang goat meat emulsion. This could be due to the ability of starches to act as fillers in meat emulsion, which aids in the formation of a more compressed and stronger heat-induced protein network (Li & Yeh, 2002). The present work demonstrated that %TEF and %EFAT were significantly reduced after being incorporated with tapioca starch (TS), thus indicating the highest emulsion stability. Similarly, Ismail *et. al.* (2021a) observed the least %TEF and %EFAT as indicators of stable meat emulsion. Hughes *et al*. (1998) also reported improved emulsion stability of frankfurters upon the incorporation of tapioca starch and attributed to higher binding of water and fat molecules, thereby lowering fat globule mobility. Further, as starch gelatinization occurs during the heating process, it indirectly helps more water molecules to be attached to the said meat product.

Incorporating starches into meat emulsion did not significantly affect the pH of both raw and cooked meat emulsion but significantly lowered cooking loss ($P\leq0.05$) as compared to the control. The WHC of the meat emulsion was also marginally increased ($p>0.05$) by the incorporation of those starches. The pH values for both raw and cooked samples were not significantly different ($p>0.05$) from the control. The incorporation of various flours or starches did not affect the pH of goat meat as the pH for fresh goat meat was between 5.8 to 6.2 (Simela *et al*., 2004). Similarly, Pietrasik and Janz (2010) also reported a non-significant effect of starch and pea flour addition on the pH of low-fat bologna pH. In addition, it was found that there was an increase in pH after the meat emulsions were exposed to heat which is in line with Ismail *et. al*. (2022), who reported a higher pH of cooked buffalo meat patties treated with roselle, wolfberry, and beetroot purees. Protein denaturation occurs as the meat is exposed to heat causing the pH to rise due to the release of peptides and amines (Roberts & Lawrie, 1974).

Table 2. Emulsion stability, pH, cooking loss, and water holding capacity of Katjang goat meat emulsions incorporated with different starches

Sample	Emulsion stability		pH		Cooking loss (%)	Water holding capacity (%)
	%TEF	%EFAT	Raw	Cooked		
Control	18.43±6.64^{A}	4.91±1.85^{AB}	5.49±0.10^{A}	5.77±0.09^{A}	27.59±3.77^{A}	51.08±2.74^{A}
TS	4.93±3.06^{B}	0.63±0.59^{B}	5.32±0.21^{A}	5.77±0.00^{A}	7.96±9.62^{B}	52.26±1.98^{A}
SS	15.80±3.72^{A}	7.32±3.42^{A}	5.38±0.22^{A}	5.67±0.17^{A}	9.87±3.76^{AB}	53.82±0.73^{A}
WS	3.93±0.77^{B}	3.73±3.41^{AB}	5.64±0.18^{A}	5.80±0.00^{A}	8.48±9.56^{B}	51.96±1.35^{A}

Note: TS; tapioca starch, SS; sago starch, WS; wheat starch, total expressible fluid, EFAT; expressible fat. Means followed by different uppercase superscripts in the same column are significantly different (p<0.05)

Cooking loss is one of the most important indicators of water retention capacity in meat emulsion along with WHC and thawing loss (Du *et. al*., 2020). The result in Table 2 below proves the incorporation of starches into the Katjang goat meat emulsion formulation significantly reduced (P<0.05) cooking loss. In addition, the cooking loss can also be used to identify the emulsification stability of the meat emulsion (Ismail *et al*., 2021a). Katjang goat meat emulsion incorporated with TS significantly minimized the cooking loss when compared with control goat meat emulsion, thus, significantly (P<0.05) improving the emulsion stability. This is due to the ability of starches, which belong to a hydrocolloid group thereby attract surrounding water via water binding sites of its polar groups (Mejia *et al*., 2019). Without the assistance of additional starches, meat emulsion that is exposed to high heat during a cooking process leads to protein damage and network structure dissipation, consequently increasing cooking loss (Lv *et al*., 2021). However, the present work demonstrated that the starch addition did not improve the WHC of the goat meat emulsions. In line with a study by Ismail *et al*. (2022), the study suggested that the treatments did not protect the free water movement from the patties by gravity.

Proximate analysis

There was no significant difference (P>0.05) observed in ash, moisture content, crude protein, and carbohydrate content of Katjang goat meat emulsion incorporated with different starches (Table 3). However, the addition of starches to Katjang goat meat emulsion was found to significantly (p<0.05) decrease the fat content of the emulsion as compared with the control sample. The proximate composition of Katjang goat meat emulsion indicated that the incorporation of starches into meat emulsion formulations affected the proximate composition of the patties. The ash, moisture, crude protein, and carbohydrate contents did not differ between the goat meat emulsions added with different starches, which is likely due to starches did not contribute much to the compositions stated (ash, moisture, crude protein, & carbohydrate). This finding is in line with a study by Rezler *et al*. (2021) which stated the protein content of pork liver pâtés was not affected by incorporating modified starch. However, the carbohydrate content of the Katjang goat meat emulsion a higher value of carbohydrate after being incorporated with the different types of starches. This is due to starches being one of the sources of carbohydrates mainly found in the human diet (Yang *et al*., 2022). Similarly, a study carried out by Osman *et al*. (2022) reported similar findings in which the carbohydrate content of beef patties with the incorporation of starch as a fat replacer increased as compared with the control treatment.

Table 3. Proximate analysis of Katjang goat meat emulsion incorporated with different starches

Sample	Ash (%)	Moisture (%)	Crude protein (%)	Crude fat (%)	Carbohydrate (%)
Control	1.68±0.12^{A}	61.51±0.89^{A}	14.25±2.15^{A}	12.97±1.34^{A}	10.84±2.14^{A}
TS	1.69±0.06^{A}	62.35±2.08^{A}	11.88±2.18^{A}	4.88±1.43^{AB}	20.46±0.53^{A}
SS	1.73±0.11^{A}	62.03±1.92^{A}	13.80±2.54^{A}	3.03±3.81^{B}	17.94±5.90^{A}
WS	1.63±0.21^{A}	61.40±1.75^{A}	13.45±3.32^{A}	3.13±1.62^{B}	18.52±4.67^{A}

Note: TS; tapioca starch, SS; sago starch, WS; wheat starch. Means followed by different uppercase superscripts in the same column are significantly different (P<0.05).

Color

Table 4 shows the effects of incorporating different starches on the color attributes in Katjang goat meat emulsions. There was no significant difference (p>0.05) between L* (lightness), b* (yellowness), and a* (redness) of raw and cooked samples although different types of starch were used. In raw and cooked samples of Katjang goat meat emulsions, the L*, a*, and b* values were not significantly affected after adding starches into the formulations. Nevertheless, the a* values of the meat emulsions were found to be lower after incorporating starches in the formulation. This might be due to the color of the starches being originally white, thus reducing the redness of the meat emulsions. This is in line with a finding by Zhang *et al*. (2013) that adding starches in raw surimi-beef gels formulations reduced the a* values.

Table 4. Color profile of raw and cooked Katjang goat meat emulsion incorporated with different starches

Sample	L*		a*		b*	
	Raw	Cooked	Raw	Cooked	Raw	Cooked
Control	42.87±3.75^{A}	42.46±5.01^{A}	12.79±1.60^{A}	6.67±1.10^{A}	8.72±0.46^{A}	10.79±2.40^{A}
TS	49.12±4.75^{A}	40.15±3.16^{A}	10.50±1.48^{A}	5.74±1.61^{A}	10.22±1.92^{A}	9.55±0.84^{A}
SS	44.55±0.35^{A}	38.86±0.98^{A}	11.01±1.34^{A}	5.62±1.63^{A}	9.01±1.26^{A}	9.19±0.83^{A}
WS	44.54±2.29^{A}	38.13±2.63^{A}	10.80±1.70^{A}	5.21±1.1^{A}	8.69±1.55^{A}	8.45±0.60^{A}

Note: TS; tapioca starch, SS; sago starch, WS; wheat starch. Means followed by different uppercase superscripts in the same column are significantly different (P<0.05).

Texture profile analysis (TPA)

There was no significant difference found in the texture profile analysis (TPA) of Katjang goat meat emulsions incorporated with different starches (Table 5). Nevertheless, the addition of TS and SS almost retained the same springiness properties as the control meat emulsion. However, it was found that incorporating WS in Katjang meat emulsion had the lowest springiness (0.18±0.09 mm). Moreover, incorporating starches in Katjang goat meat emulsion was also found to decrease the cohesiveness, gumminess, chewiness, and resilience of the meat emulsion. Meat emulsions with SS had the lowest cohesiveness and gumminess which were 0.35±0.06 and 2889±1213 g, respectively. Furthermore, adding WS into Katjang goat meat emulsion resulted in the lowest chewiness and resilience of the meat emulsion which was 2087±741 g.mm and 0.11±0.02. Even though the texture profile analyses were not significantly different, it was observed that adding starches into goat meat emulsion formulation decreased (p>0.05) the hardness, chewiness, springiness, cohesiveness, gumminess, and resilience of the meat emulsion. Similarly, Ensor *et al*. (1987) also found no significant difference was made to the springiness of cooked sausages after being treated with a variety of types and levels of binder used in the treatments.

Table 5. Texture profile analysis (TPA) of Katjang goat meat emulsion incorporated with different starches.

Sample	Hardness (g)	Springiness (mm)	Cohesiveness	Gumminess (g)	Chewiness (g.mm)	Resilience
Control	9787±3262^{A}	0.73±0.06^{A}	0.43±0.03^{A}	4167±1350^{A}	3097±1180^{A}	0.14±0.01^{A}
TS	8571±1080^{A}	0.78±0.02^{A}	0.39±0.06^{A}	3360±674^{A}	2608±552^{A}	0.14±0.03^{A}
SS	8185±2075^{A}	0.73±0.06^{A}	0.35±0.06^{A}	2889±1213^{A}	2117±927^{A}	0.12±0.02^{A}
WS	8046±1685^{A}	0.18±0.09^{A}	0.36±0.04^{A}	2893±824^{A}	2087±741^{A}	0.11±0.02^{A}

Note: TS; tapioca starch, SS; sago starch, WS; wheat starch. Means followed by different uppercase superscripts in the same column are significantly different (P<0.05).

Shear force and work of shear

Based on Table 6, incorporating starches into the Katjang goat meat emulsion formulation produced significant differences (P<0.05) in the work of shearing of the meat emulsion as compared to the control Katjang goat meat emulsion. It was observed that Katjang goat meat emulsion incorporated with SS had the lowest shear force and shear of working which were 0.60±0.05 N and 6.56±1.45 N.s, respectively. The present study observed that adding extra non-meat ingredients caused the shear force and work of shearing to decrease. This is in line with Kamani *et al*. (2019) who concluded incorporation of additional starch and flour declined its shear force as starch and flour may interrupt the stromal and myofibrillar protein that is in charge of the firmness of the meat product and cause the product to be softer.

Table 6. Shear force and work of shear of Katjang goat meat emulsion incorporated with different starches.

Sample	Shear force (N)	Work of shearing (N.s)
Control	3.11±2.79^{A}	15.42±5.65^{A}
TS	0.83±0.08^{A}	8.40±0.38^{AB}
SS	0.60±0.05^{A}	6.56±1.45^{B}
WS	0.67±0.06^{A}	8.63±0.09^{AB}

Note: TS; tapioca starch, SS; sago starch, WS; wheat starch. Means followed by different uppercase superscripts in the same column are significantly different (P<0.05).

CONCLUSION

The incorporation of tapioca starch (TS) into Katjang goat meat emulsion was beneficial in forming a stable meat emulsion as it produced meat emulsion with the lowest %TFE %EFAT and cooking loss. No significant changes were found for the other analyses which are pH, WHC, texture profile analysis, lightness (L*), and redness (b*) values of the Katjang goat meat emulsions. This showed incorporating tapioca starch (TS) in the meat emulsion formulation improved the stability of the meat emulsion without compromising other physical properties as compared with the control sample.

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ETHICAL STATEMENT

Not applicable.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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