International Food Research Journal 28(5): 916 - 925 (October 2021)

Journal homepage: *http://www.ifrj.upm.edu.my*

Effect of different levels of fat, sodium chloride, and sodium tripolyphosphate on the physicochemical and microstructure properties of Jamnapari goat meat emulsion modelling system

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Article history

Received: 1 February 2021
Received in revised form: 25 May 2021
Accepted: 16 June 2021

Keywords

emulsion stability, goat meat, Jamnapari breed, meat products, meat quality

Abstract

Jamnapari goat meat has the potential to be used for producing quality meat products. The present work thus aimed to evaluate the properties of Jamnapari meat emulsion. A two-level factorial design with three independent variables (2^3), fat (10 and 30%), sodium chloride (NaCl) (0.8 and 2.4%), and sodium tripolyphosphate (STPP) (0.5 and 1.5%) was used to randomly produce eight formulations of Jamnapari goat meat emulsion. The total expressible fluid (%TEF), expressible fat (%EFAT), pH, cooking loss, water holding capacity (WHC), texture, and microstructure properties of the eight Jamnapari goat meat emulsions were analysed. The %TEF was highly influenced by all factors (fat, NaCl, and STPP), while the %EFAT was only affected by the amount of fat. The pH and cooking loss were affected by fat and STPP levels, while the WHC was affected by the NaCl level. The hardness of the cooked Jamnapari meat emulsion was influenced by all the factors, while the cohesiveness by the fat and NaCl, the springiness by the fat content, and the gumminess, chewiness, and resilience by the STPP. A high NaCl level resulted in a homogeneous microstructure and smaller fat droplets. Although Formulation 3 (10% fat, 2.4% NaCl, and 0.5% STPP) showed good results in emulsion stability, cooking loss, WHC, textural properties, and uniform fat distribution within the meat protein matrix, Formulation 7 (10% fat, 0.8% NaCl, and 0.5% STPP) could be more preferable for its lower salt level. To conclude, the present work developed a stable formulation of Jamnapari goat meat emulsion that can be used to produce meat products.

Introduction

Jamnapari or Jamunapari is a goat breed originating from the Indian subcontinent, and mainly found in the Etawah district of Uttar Pradesh. It has been successfully exported and bred in other countries such as Malaysia, Indonesia, Thailand, Nepal, and Bangladesh, and is well known for its superior meat quality (Pralomkarn and Boonsanit, 2012). Jamnapari goat meat is healthier with low cholesterol (71.76 mg/100 mg) and fat (1.98%) contents (Das and Rajkumar, 2010) as compared to other goat breeds which have higher cholesterol and fat contents such as Boer (82 mg/100 g cholesterol, and 10.5% fat), and Marwari (73.45 mg/100 g cholesterol, and 2.35% fat) (Werdi Pratiwi *et al.,* 2006; Das and Rajkumar, 2010; Webb, 2014). It is usually consumed during festive seasons as in curry, while its minced meat is used to make kebabs. However, its use to produce other meat products such as patties, sausages, and meatballs is rather limited. Fundamentally, these products are produced from a stable meat emulsion consisting of meat protein, water, fat, salt, phosphate, and other additional ingredients (Hughes *et al.,* 1997; Crehan *et al.,* 2000; Wang *et al.,* 2009).

A meat emulsion is a mixture of two physically different phases; a disperse phase made up of fat globules, and a continuous phase of a gel-like medium consisting of a matrix of water, soluble myofibrillar proteins, salts, phosphates, and other non-meat ingredients. The meat protein acts as an emulsifying agent, whereby myosin, the major structural meat protein, surrounds the finely chopped fat particles to facilitate an oil-water interface (Sorapukdee *et al.,* 2013). Animal fat used in meat emulsions has special characteristics, thus providing a unique texture to various emulsion-based meat products (Pehlivanoğlu *et al.,* 2018). Incorporating animal fats into the formulation not only has major

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DOI:
https://doi.org/10.47836/ifrj.28.5.04

effects on the emulsion characteristics, but also helps to ameliorate textural properties, mouthfeel, flavour, and stabilisation, as well as aiding the overall lubricity of foods (Jiménez-Colmenero, 2000).

Commercial or table salt (sodium chloride; NaCl) is commonly added to meat emulsions, functioning as a flavour enhancer and promoting gelling properties (Jiao, 2019). NaCl can solubilise protein by extracting myosin from muscle fibres, consequently improving the emulsion stability, water holding capacity, the yield of the batter, and processing stability as the encapsulation of salt and protein solution together in a mixture formed an emulsion (Kim *et al.,* 2010). Phosphate such as sodium tripolyphosphate (STPP) is also widely used in meat emulsions to improve the product yield, water holding capacity by increasing the pH of the meat batter, and help to extract protein muscles (Wang *et al.,* 2009; Choe *et al.,* 2018). Both NaCl and STPP work synergistically to extract and solubilise proteins, especially myofibrillar protein that enhances the meat batter textural properties such as tenderness and juiciness, cooking yield, and eating quality (Desmond, 2006).

In producing the desired stable emulsion, each ingredient has an important function Previous studies have investigated different quantities of each non-meat ingredient in beef and pork emulsions (Puolanne *et al.,* 2001; Steen *et al.,* 2014; Kim *et al.,* 2015; Vasquez Mejia *et al.,* 2019; Câmara *et al.,* 2020; Yang *et al.,* 2021), but there is limited information on the effects of fat, NaCl, and STPP in Jamnapari goat meat emulsions. Therefore, the present work evaluated the effect of incorporating different quantities of animal fat from Jamnapari goat, NaCl, and STPP on the physicochemical and microstructure properties of Jamnapari goat meat emulsions. The findings are expected to highlight the optimal fat, NaCl, and STPP content to produce the desired Jamnapari emulsion for the potential production of meat products.

Materials and methods

Experimental design

Each meat emulsion formulation was produced using a 2^3 full factorial design arrangement, evaluating three factors (levels of fat, NaCl, and STPP) at two different levels (fat% = 10 and 30, NaCl% = 0.8 and 2.4, and STPP% = 0.5 and 1.5). A total of eight random formulation combinations were produced (Table 1), and the experiments were performed in triplicate.

Preparation of meat emulsion

Jamnapari goat meat (from the hind legs) and fat were purchased from a meat shop in the Seri Kembangan wet market (Selangor, Malaysia), and dry ingredients such as NaCl and STPP were purchased from Mei Loon Sdn. Bhd. (Klang, Selangor). The meat emulsions were prepared following the procedures described by Vasquez Mejia *et al.* (2018) with slight modifications. Eight formulations consisting of 100 g of Jamnapari meat emulsion with various quantities of other ingredients were produced as shown in Table 1. First, the required amount of goat meat and fat were thawed and ground separately using a meat mincer through a 3 mm pore size (Hobart, USA). Then, the ground meat was mixed with the required amount of NaCl, STPP, and 4 g of crushed ice for 30 s using a food blender (Pensonic PB-3203L, Malaysia) before the pre-weighed fat was added and mixed for another 15 s. Another 4 g of crushed ice was added and mixed for 20 s until the emulsion was homogenised for a total of 1 min. During emulsification, the temperature of the meat emulsion was monitored and maintained below 10°C.

Table 1. Formulations generated based on 10 and 30% of fat, 0.8 and 2.4% of NaCl, and 0.5 and 1.5% of STPP.

Formulation	Meat (%)	Ice (%)	Fat (%)	NaCl (%)	STPP (%)
F1	79.7	8.0	10.0	0.8	1.5
F2	60.7	8.0	30.0	0.8	0.5
F3	79.1	8.0	10.0	2.4	0.5
F4	58.1	8.0	30.0	2.4	1.5
F5	59.7	8.0	30.0	0.8	1.5
F6	78.1	8.0	10.0	2.4	1.5
F7	80.7	8.0	10.0	0.8	0.5
F8	59.1	8.0	30.0	2.4	0.5

Emulsion stability

The emulsion stability was determined based on the total expressible fluid and fat following the procedures described by Hughes *et al.* (1997). The sample was weighed (25 g) and centrifuged (Kubota 3740, Japan) at 4,000 rpm for 1 min, then heated in a water bath at 70°C for 30 min before centrifugation at 4,000 rpm for 3 min. The supernatants were poured into pre-weighed crucibles, and dried overnight in the oven at 100°C, while the pelleted samples obtained were weighed. The volumes of total expressible fluid (TEF) and the expressible fat (EFAT) were calculated using Eqs. 1, 2, and 3:

TEF = (weight of centrifuge tube + weight of the sample) – (weight of centrifuge tube + weight of the pellet) (Eq. 1)

%TEF = TEF / (weight of sample) × 100 (Eq. 2)

%EFAT = [(weight of crucible + weight of dried supernatant) – (weight of empty crucible)] / TEF × 100 (Eq. 3)

pH

The pH was measured using a pH meter (Eutech pH 2700, Singapore) equipped with a pH electrode according to Choi *et al.* (2011). Five gram of each sample and 20 mL of distilled water were mixed in a beaker until homogenous before pH measurement.

Water holding capacity

The WHC was determined following the procedures described by Isabel *et al.* (2006) with slight modification, according to Alemán *et al.* (2016). The thawed meat emulsion (1.5 g) was placed in a centrifuge tube with a filter paper (Whatman No. 1), and centrifuged for 15 min using a refrigerated microcentrifuge (Kubota 3740, Japan) at 20°C and 4,000 *g*. The WHC was determined using Eqs. 4 and 5:

Expressible moisture = [(weight of centrifuge tube + weight of the sample) – (weight of centrifuge tube + weight of the pellet)] / (weight of sample) × 100 (Eq. 4)

WHC (%) = 100% – expressible moisture (Eq. 5)

Cooking loss

The cooking loss was calculated following the procedures described by Vasquez Mejia *et al.* (2018) with a slight modification. Briefly, 5 g of each sample was weighed and placed into a centrifuge tube, then centrifuged (Kubota 3740, Japan) at 1,000 *g* for 40 s to remove air bubbles. The samples were then immersed in the pre-heated water bath at 50°C, and the temperature was increased until the sample reached an internal temperature of 72°C, measured using a thermocouple. The centrifuge tubes were cooled in a cold-water bath for 5 min, and the exudates released. The pelleted samples were weighed, and the results expressed using Eq. 6:

Cooking loss (%) = [(weight of the uncooked sample – weight of the pellet) / weight of the uncooked sample] × 100 (Eq. 6)

Light micrographs of meat emulsion

The micrographs of the emulsion were acquired following the procedures described by Zhang *et al.* (2013) with slight modification. Briefly, a small amount of meat emulsion was spread thinly on the slide, and air-dried at 4°C. Then, the dried slides were immersed in 1% bromophenol blue solution for 3 min, washed with distilled water, re-immersed in diluted Sudan III solution for 3 min, washed with distilled water, and air-dried at 4°C. The slides were viewed, and micrographs acquired using a light microscope at 60× magnification (Nikon Eclipse 80i Binocular, Japan).

Texture profile analysis

The meat emulsion was cooked, and its cooking loss and textural properties were measured using a texture analyser (TA-XT2i Stable MicroSystems, London) following the procedures described by Álvarez and Barbut (2013) with slight modifications. Briefly, the cooked emulsions were cut into cylindrical cores measuring 10 mm length × 20 mm diameter, and compressed twice with 30 kg load to 75% of their original height using a P/75 probe (75 mm diameter) at a test speed of 1.5 mm/s and post-test speed of 1.5 mm/s. The parameters measured were hardness (g), springiness (mm), cohesiveness, gumminess (g), chewiness (g.mm), and resilience.

Statistical analysis

A 2^3 full factorial design was employed to investigate the effects and select the optimal values by testing the lower and upper limits of different quantities of fat (10 and 30%), NaCl (0.8 and 2.4%), and STPP (0.5 and 1.5%) in producing the most stable Jamnapari goat meat emulsion. One-way ANOVA was performed using Minitab 19 software (Minitab, USA) for statistical analysis of factorial design, whereby the factors influenced were observed with a level of significance set at $p < 0.05$.

Results and discussion

Emulsion stability, pH, WHC, and cooking loss

Emulsion stability is often observed and measured to identify the capability of an emulsion to withstand any property changes that occur over time. A more stable emulsion has less total expressible fluid (%TEF) and fat (%EFAT) (Serdaroğlu *et al.,* 2016). The fat, NaCl, and STPP contents could influence the %TEF and %EFAT, as well as the pH, WHC, and cooking loss. Table 2 shows that the fat, NaCl, and STPP contents had a significant impact on the %TEF, while there was a significant interaction effect between the NaCl and STPP contents on the %TEF observed in the Jamnapari meat emulsion formulation. Meanwhile, only the fat content significantly affected the %EFAT, with a significant interaction effect between the fat and STPP contents on the %EFAT.

Table 3 presents the effect of each formulation on the %TEF, %EFAT, pH, WHC, and cooking loss. F6 (10% fat, 2.4% NaCl, and 1.5% STPP) had significantly the least %TEF and second least %EFAT (5.574 ± 1.01 and 10.75 ± 1.24, respectively), thus indicating high emulsion stability. A high salt content aids in the extraction of myofibrillar meat proteins, thus facilitating more effective protein binding to water and fat, and preventing the emulsion from losing water and fat during cooking (Weiss *et al.,* 2010). It has been suggested that 1.30% salt or more would be significant to form a stable meat emulsion (Crehan *et al.,* 2000). Additionally, Kim *et al.* (2015) reported that increased salt incorporated in a meat emulsion resulted in lower %TEF and %EFAT. Furthermore,

Table 2. Statistical analysis of emulsion stability and pH of Jamnapari goat meat emulsions using 2^3 factorial design.

	Emulsion stability				pH		Cooking loss		WHC	
	%TEF		%EFAT							
	Effect	*p*-value	Effect	*p*-value	Effect	*p*-value	Effect	*p*-value	Effect	*p*-value
Fat	11.45	0.000	16.731	0.000	-0.07083	0.000	5.919	0.000	-0.373	0.781
NaCl	-5.26	0.020	-2.803	0.151	-0.02583	0.103	1.912	0.104	3.671	0.013
STPP	-12.46	0.000	-2.579	0.184	0.39250	0.000	-10.581	0.000	1.149	0.395
NaCl*Fat	0.61	0.766	1.105	0.560	-0.09083	0.000	-1.011	0.376	1.545	0.258
NaCl*STPP	5.98	0.009	-0.364	0.847	-0.06750	0.000	2.837	0.021	-0.401	0.764
Fat*STPP	1.37	0.508	-5.981	0.005	-0.07917	0.000	-0.759	0.504	1.236	0.362
NaCl*Fat*STPP	0.44	0.831	2.574	0.185	0.12083	0.000	0.920	0.419	-0.280	0.834

Table 3. One-way ANOVA of different formulations of Jamnapari goat meat emulsions with %TEF, %EFAT, pH, WHC, and cooking loss.

Formulation	%TEF	%EFAT	pH	Cooking loss (%)	WHC (%)
F1	5.91 ± 1.12^{C}	17.60 ± 1.28^{BC}	6.71 ± 0.01^{A}	19.60 ± 2.56^{E}	86.51 ± 4.13^{A}
F2	35.19 ± 1.02^{A}	35.44 ± 3.40^{A}	6.27 ± 0.06^{D}	39.95 ± 1.06^{A}	84.80 ± 3.89^{A}
F3	13.87 ± 3.72^{BC}	10.29 ± 1.74^{C}	6.30 ± 0.02^{D}	32.35 ± 2.93^{ABC}	84.58 ± 0.75^{A}
F4	19.45 ± 3.49^{BC}	25.19 ± 4.01^{AB}	6.46 ± 0.04^{C}	29.51 ± 3.43^{BCD}	84.38 ± 1.58^{A}
F5	17.68 ± 10.03^{BC}	24.67 ± 8.26^{AB}	6.53 ± 0.07^{BC}	24.86 ± 3.42^{CDE}	82.37 ± 3.52^{A}
F6	5.57 ± 1.01^{C}	10.75 ± 1.24^{C}	6.58 ± 0.02^{B}	24.44 ± 3.62^{DE}	82.34 ± 4.64^{A}
F7	25.29 ± 2.14^{AB}	11.26 ± 2.63^{C}	6.05 ± 0.01^{E}	31.34 ± 2.30^{BCD}	81.97 ± 2.33^{A}
F8	24.12 ± 7.95^{AB}	31.53 ± 7.54^{A}	6.10 ± 0.01^{E}	37.10 ± 1.07^{AB}	78.90 ± 2.95^{A}

Means followed by different uppercase superscripts in the same column are significantly different.

the inclusion of 2.0 or 2.5% salt in a meat batter provided the greatest emulsion stability as less fluid was lost as compared to a lower salt content (Felisberto *et al.,* 2015).

Decreasing the amount of STPP to 0.5% while maintaining the NaCl and fat levels in F3 (10% fat, 2.4% NaCl, and 0.5% STPP) resulted in the second most stable Jamnapari meat emulsion with low %TEF and %EFAT (13.87 ± 3.72 and 10.29 ± 1.74, respectively). F3 was preferred to avoid a high phosphate level (Long *et al.,* 2011). The addition of a high amount of STPP in meat emulsion products resulted in an unacceptably bitter taste (Ranken, 2000). The maximum permitted level of phosphate in the final processed meat and poultry products is 0.5% according to the European legislation (Long *et al.,* 2011). Therefore, reducing STPP to 0.5% could be feasible to form a stable Jamnapari meat emulsion with an acceptable taste. In contrast, F2 (30% fat, 0.8% NaCl, and 0.5% STPP) was the least stable with the highest %TEF and %EFAT (35.19 ± 1.02 and 35.44 ± 3.40, respectively). Higher fat, and lower NaCl and STPP levels could affect the %TEF. STPP has been proven to improve WHC, and work with salt to enhance the stability of the meat emulsion (Choe *et al.,* 2018). In the present work, the %EFAT might be affected by the inclusion of fat, where the fat loss increased as the fat level increased to 30%.

The fat and STPP levels had significant effects on the pH, while all factors exhibited a significant interaction effect on pH (Table 2). F1 (10% fat, 0.8% NaCl, and 1.5% STPP) had the highest pH value (6.71 ± 0.01), while F7 (10% fat, 0.8% NaCl, and 0.5% STPP) had the lowest (6.05 ± 0.01) (Table 3). The difference in pH among these two formulations was due to the addition of STPP which increased the pH in the meat emulsion (Puolanne *et al.,* 2001). Alkaline phosphate can affect the pH of the meat emulsion as 1% STPP has a pH of 9.8 (Long *et al.,* 2011). Thus, a higher STPP content might result in a higher pH of the Jamnapari meat emulsion. Similar trend has been reported by Vasquez Mejia *et al.* (2019), where the pH of beef emulsion increased after the addition of alkaline sodium phosphate. Puolanne *et al.* (2001) reported a similar finding for the interaction effects of salt and phosphate in cooked meat products. Additionally, Das *et al.* (2008) reported that the pH of controlled goat meat emulsion was in the range of 6.05 and 6.45.

The cooking loss was determined to assess the inability of the meat emulsion to retain water and fat during protein denaturation, which impacts the commercial aspect and consumer acceptance (Tahmasebi *et al.,* 2016). The inclusion of fat and STPP had a significant effect on the cooking loss, with a significant interaction effect between NaCl and STPP levels on the cooking loss was observed as shown in Table 2. F2 had the most effect on cooking loss, while F1 had the least (Table 3). During the cooking process, 70 - 80% of the mass reduction of the sample is lipid (Webb *et al.,* 2005); thus, the high fat content in F2 resulted in more cooking loss as the fat was released during cooking. Gujral *et al.* (2002) reported an increasing cooking loss from 38.6 to 42.9% as the fat inclusion level increased from 0 to 15%. F7 and F3 were the second and third best formulations to prevent cooking loss if based on the lower levels of STPP.

According to Qi *et al.* (2020), cooking loss can be used as the indicator of the WHC of meat products during cooking, thus identifying the emulsification stability of the meat emulsion. Similar trend was observed in the present work, where the emulsion with the least cooking loss had the most WHC (F1). The different levels of NaCl tested had a significant ($p < 0.05$) effect on WHC (Table 2). Although there was no significant difference between the Jamnapari goat meat emulsion formulations for the WHC (Table 3), it is important to note that the lowest STPP quantity included in F3 (fat 30%, NaCl 2.4%, and STPP 0.5%) had the best WHC, as the emulsion retained most water. Nevertheless, since there were no significant differences between the formulations, the lower NaCl (0.8%) content of the Jamnapari meat emulsion is preferred for taste acceptability and health reasons.

Light microscopy

Figure 1 shows the distribution and shape of the fat particles in uncooked Jamnapari meat emulsions prepared with different levels of fat, NaCl, and STPP. The fat droplets in the protein matrix were irregular in shape but mostly oval, surrounded by a protein film in raw meat emulsion as reported by Zhang *et al.* (2013). According to Steen *et al.* (2014), incorporating high fat in meat emulsion leads to less adsorption at the oil/water interface as fewer proteins are available to coalesce the fat, eventually forming larger fat droplets. Figure 1 also shows that the high concentration of different-sized fat droplets was unevenly distributed and clumped in the protein matrix of the Jamnapari meat emulsion in F2 (30% fat, 0.8% NaCl, and 0.5% STPP), which may be directly related to its lowest emulsion stability (Table 3). Similar result was reported by Steen *et al.* (2014). In contrast, smaller and lesser fat globules were found in the Jamnapari meat emulsions formulated with only 10% fat (F1 and F3). Phosphates act very efficiently in increasing the solubility of proteins (Câmara *et al.,* 2020). In F6 (2.4% NaCl, 10% fat, and 1.5% STPP), the fat droplets were well distributed, and uniform in size and shape. The high level of STPP in this formulation might be the reason for its highest emulsion stability.

Incorporating more NaCl (2.4%) resulted in smaller and more uniform fat droplets in the Jamnapari meat emulsion of F3, F4, F6, and F8, due to the ability of NaCl to extract and solubilise the meat protein, and it is most likely caused by the chaotropic effect producing weaker intermolecular hydrogen bonds in a medium that contains more polar salt and/or attracting charged groups of protein (Steen *et al.,* 2014). As shown in Figure 1, F3 had the lowest concentration of fat droplets in the meat emulsion. More non-emulsified protein matrix was found in F2, F5, and F7 due to the lower NaCl content as less NaCl was available to assist in the emulsification of the protein and fat.

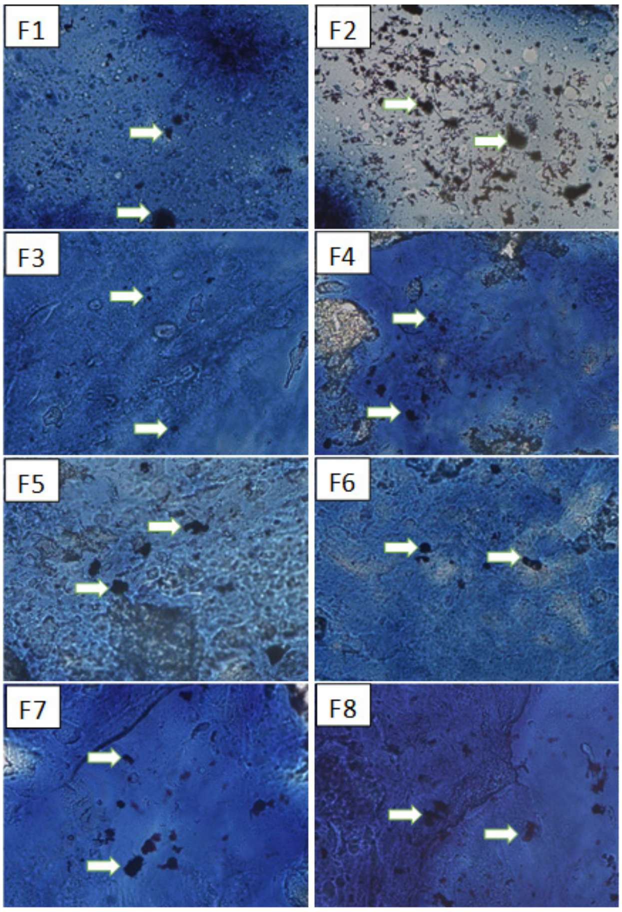

Figure 1. Light photomicrograph of double-dyed meat emulsions (F1 - F8: 60× magnification). F1(10% Fat, 0.8% NaCl, and 1.5% STPP); F2 (30% Fat, 0.8% NaCl, and 0.5% STPP); F3 (10% Fat, 2.4% NaCl, and 0.5% STPP); F4 (30% Fat, 2.4% NaCl, and 1.5% STPP); F5 (30% Fat, 0.8% NaCl, and 1.5% STPP); F6 (10% Fat, 2.4% NaCl, and 1.5% STPP); F7 (10% Fat, 0.8% NaCl, and 0.5% STPP); F8 (30% Fat, 2.4% NaCl, and 0.5% STPP). The light colour background represents water and muscle proteins, and the dark colour represents fats (pointed by the arrows).

Textural properties of the cooked emulsion

One of the most important factors in choosing processed food product is its textural properties, which can be changed by using different ingredients due to the degree of myofibrillar protein extraction, stromal protein, degree of comminuting, and non-meat ingredient content (Serdaroğlu *et al.,* 2016). Hardness is one of the most important textural properties as it affects the commercial value of meat products, and represents the force required to break the food during chewing (Nurul *et al.,* 2010). The inclusion of fat, NaCl, and STPP had a highly significant effect on the hardness of cooked meat emulsions (Table 4). There were no significant differences in hardness between formulations, except between F4 (30% fat, 2.4% NaCl, and 1.5% STPP) (15063 ± 393) and F2 (30% fat, 0.8% NaCl, and 0.5% STPP) (10479 ± 1211) ($p < 0.05$). Higher NaCl and STPP levels in F4 might be the reason for the harder texture of meat emulsion as compared to F2 as both formulations had the same level of fat (30%). Phosphates such as sodium tripolyphosphates (STPP) and tetrasodium pyrophosphate (TSPP) enhance the yield, palatability characteristics, water retention, and sensory tenderness without affecting product yields. Also, a lower salt content in a gel-emulsion system results in less solubilised protein; hence, insufficient aggregation of protein might occur and create a firm protein network (Cofrades *et al.,* 2008). The higher NaCl level in F4 (30% fat, 2.4% NaCl, and 1.5 STPP) resulted in a higher hardness value than the lower NaCl level in F5 (30% fat, 0.8% NaCl, and 1.5% STPP). However, F7 (10% fat, 0.8% NaCl, and 0.5% STPP) with a much lower fat, NaCl and STPP levels had the second-highest hardness value, thus indicating that it is possible to reduce the amount of fat, NaCl, and STPP and still achieve a Jamnapari meat emulsion with the preferred hardness. Goat meat has thicker muscle fibres and lower fat contents; thus, it is harder than other meats such as lamb (Babiker *et al.,* 1990). Therefore, goat meat products tend to have high hardness values than other livestock meat products. Additionally, a study claimed that consumers preferred goat meat frankfurter with a hard textural property (Bratcher *et al.,* 2011).

Springiness was affected by the inclusion of fat in the meat emulsion formulation, with an increased fat content significantly reducing the

Table 4. Statistical analysis of textural properties of the cooked Jamnapari goat meat emulsions using 2^3 factorial design.

	Hardness (g)		Springiness (mm)		Cohesiveness		Gumminess (g)		Chewiness (g.mm)		Resilience	
	Effect	***p*-value**	**Effect**	***p*-value**	**Effect**	***p*-value**	**Effect**	***p*-value**	**Effect**	***p*-value**	**Effect**	***p*-value**
Fat	11.45	0.000	16.731	0.000	-0.07083	0.000	619	0.143	344	0.274	0.01075	0.161
NaCl	-5.26	0.020	-2.803	0.151	-0.02583	0.103	-7	0.986	-109	0.723	0.00308	0.679
STPP	-12.46	0.000	-2.579	0.184	0.39250	0.000	886	0.043	839	0.014	0.01742	0.030
NaCl*Fat	0.61	0.766	1.105	0.560	-0.09083	0.000	191	0.640	-3	0.993	-0.00208	0.780
NaCl*STPP	5.98	0.009	-0.364	0.847	-0.06750	0.000	441	0.289	440	0.166	0.00492	0.511
Fat*STPP	1.37	0.508	-5.981	0.005	-0.07917	0.000	1556	0.001	1193	0.001	0.02992	0.001
NaCl*Fat*STPP	0.44	0.831	2.574	0.185	0.12083	0.000	269	0.513	184	0.552	0.00342	0.647

Table 5. One-way ANOVA of different formulations of the cooked Jamnapari goat meat emulsions with textural properties.

Formulation	Hardness (g)	Springiness (mm)	Cohesiveness	Gumminess (g)	Chewiness (g.mm)	Resilience
F1	11522 ± 835^{AB}	0.73 ± 0.02^{A}	0.47 ± 0.04^{AB}	5361 ± 525^{AB}	3914 ± 436^{AB}	0.17 ± 0.02^{AB}
F2	10479 ± 1211^{B}	0.72 ± 0.01^{AB}	0.51 ± 0.01^{AB}	5343 ± 572^{AB}	3861 ± 388^{AB}	0.17 ± 0.01^{AB}
F3	11552 ± 2858^{AB}	0.72 ± 0.02^{AB}	0.50 ± 0.04^{AB}	5833 ± 1855^{AB}	4161 ± 1189^{AB}	0.18 ± 0.03^{AB}
F4	15063 ± 393^{A}	0.73 ± 0.01^{AB}	0.53 ± 0.01^{A}	7969 ± 317^{A}	5781 ± 176^{A}	0.21 ± 0.01^{A}
F5	13988 ± 2089^{AB}	0.74 ± 0.02^{A}	0.50 ± 0.03^{AB}	7075 ± 1425^{AB}	5269 ± 1196^{A}	0.20 ± 0.02^{AB}
F6	12367 ± 1228^{AB}	0.76 ± 0.02^{A}	0.43 ± 0.03^{B}	5334 ± 852^{AB}	4063 ± 630^{AB}	0.17 ± 0.02^{AB}
F7	12699 ± 936^{AB}	0.73 ± 0.01^{A}	0.49 ± 0.01^{AB}	6203 ± 483^{AB}	4524 ± 398^{AB}	0.18 ± 0.01^{AB}
F8	11084 ± 858^{AB}	0.64 ± 0.07^{B}	0.43 ± 0.04^{B}	4818 ± 786^{B}	3125 ± 805^{B}	0.16 ± 0.02^{B}

Means followed by different uppercase superscripts in the same column are significantly different.

springiness of the cooked emulsion. F7 along with F5 and F6 had the highest springiness values, while F8 had the least. Cohesiveness was significantly affected by the fat and STPP contents. There was also a significant effect on the interactions of all the factors involved. The highest cohesiveness of the cooked meat emulsion was in F4 (0.53 ± 0.01), while the lowest was in F6 and F8 (0.43 ± 0.03 and 0.43 ± 0.04, respectively). The cohesiveness and hardness of the emulsions were directly proportional to each other; as the hardness of meat emulsion increased, the cohesiveness also increased. Furthermore, the harder meat emulsion formed a more cohesive emulsion. A study by Gujral *et al.* (2002) also reported similar trend regarding the cohesiveness of baked goat meat patties.

Gumminess, chewiness, and resilience were affected by the amount of STPP incorporated in the meat emulsion formulations. The interaction between fat and STPP levels was also observed to have a significant effect on these textural parameters. Based on ANOVA (Table 5), F4 had the highest values of gumminess, chewiness, and resilience (7969 ± 317, 5781 ± 176, and 0.21 ± 0.01, respectively), while F8 (30% fat, 2.4% NaCl, and 0.5% STPP) had the lowest (4818 ± 786, 3125 ± 805, and 0.16 ± 0.02, respectively). Phosphate improves the ability of muscle protein to extract protein; hence, meat emulsions with more incorporated phosphate form a stronger gel matrix that is preferred by consumers as they have higher chewiness and hardness (Wang *et al.,* 2009). Although F4 (30% fat, 2.4% NaCl, and 1.5% STPP) had the highest values of gumminess, chewiness, and resilience, F7 (10% fat, 0.8% NaCl, and 0.5% STPP) had the second-highest values but with less fat, NaCl, and STPP levels. Therefore, F7 could be a good choice in terms of consumers' health as well as the ability to form a stable Jamnapari meat emulsion.

Conclusion

A stable formulation of Jamnapari goat meat emulsion was optimised using a full factorial experimental design, and showed that the goat meat emulsion with 30% fat, 2.4% NaCl, and 1.5% STPP (F4) produced the best stable meat emulsion. However, as more than 0.5% STPP is not preferred in meat products, the next best formulation was F3 (10% fat, 2.4% NaCl, and 0.5% STPP), but in terms of salt content, F7 (10% fat, 0.8% NaCl, and 0.5% STPP) is preferable for health benefits while retaining a good emulsion characteristic.

Acknowledgement

The authors are thankful to Universiti Putra Malaysia for financially supporting the present work through the Putra grant scheme (grant no.: GP-IPS/2020/9686600).

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