

Research Article

Functional properties of low-fat duck sausage formulated with palm oil

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Abstract

In this study, duck meat sausages were subjected to washing processes (no washing and a single washing) and the addition of palm oil (0%, 3% and 6%); the effects of these treatments on the physicochemical and sensory qualities of the sausages were then evaluated. Carotino palm oil was used as a source of oil, and washing was carried out at a meat to water ratio of 1:1 (w/v). Samples with higher oil levels demonstrated significantly higher fat content and at the same evidence showed lower moisture and protein contents. Sample colour lightened and became less reddish after washing, and the yellowness of samples increased with fat content. Samples with lower added oil percentages had higher values for hardness and shear force, and the microstructure of the samples became less porous after washing. Sensory evaluation by 30 panellists showed that only washing without added oil affected sensory score.

Keywords: Duck meat, functional properties, microstructure, sensory evaluation, Malaysia.

Introduction

There are many varieties of frankfurters currently available on the Malaysian market; they are mainly produced from chicken, beef or fish. In the past, sausage production was performed by small family enterprises. However, increasing demand for sausage products in recent years has moved sausage manufacturing into large-scale production. Many factories have been constructed in Malaysia to enhance output and to meet increasing sausage demand. Due to the increasing competition among manufacturers, more advanced technologies have been imported from other countries, and fully-automated machineries have been introduced in order to produce high-quality products.

Washing techniques for mechanically deboned chicken meat have been investigated because of the advantages of removing fat, heme pigments and other water soluble compounds [1, 2]. Poultry meat heme removing is important to the washing process because white meat is more valuable than dark meat [3]. In addition, washing can also improve the characteristics of final products. Bhattacharyya *et*

al. [4] reported that duck sausage scored only slightly lower (non-significant) with respect to flavour as a result of its inherent duck-like odour and dark colour, nor could these invaluable characteristics be masked by spices and condiments during emulsion preparation.

The main purpose of the addition of oil in the formulation was to recover fat lost during the washing process. The role of fat is an important consideration in any formulation. From a physiological perspective, fats in foods serve three basic functions: as sources of essential fatty acids, carriers of soluble fat and vitamins and energy sources [5]. Fat also plays a major role in the texture, juiciness and flavour of comminuted meat products. The sensory properties of fats make a diet flavourful, varied and rich [6]. Fat is vital to the rheological and structural properties of meat products and in the formation of a stable emulsion [7].

Fat is important in determining the organoleptic properties of meat, and while a variety of strategies may be applied in the development of low-fat products, the basic concern has always been to reduce fat but retain traditional flavour and texture. Simply reducing fat content leads to a product of poor organoleptic quality. There are two basic methods of producing low-fat meat products: the use of fat replacers and the physical removal of fat [8]. At present, the most widely used and successful strategies involve fat replacers, though the number of physical removal methods used has begun to increase.

In this study, rich carotene palm oil (carotino oil) was added to the duck meat sausage formulation. Carotino oil is the richest natural plant source of carotenoids [9, 10]; it contains approximately 500 ppm carotene, 90% of which is present in the form of α - and β -carotene [11]. This study was carried out to observe the effect of washing (washed and unwashed samples) and the addition of oil (0%, 3% and 6%) on the physicochemical properties and sensory qualities of low-fat duck sausage.

Materials and Methods

Raw materials

Mechanically deboned duck meat was bought from Fika Food Sdn. Bhd. and immediately placed in the freezer to minimize the effect of thawing prior to processing. Other materials, including rich carotene palm oil (carotino® premium cooking oil), salt, sugar, monosodium glutamate, sodium nitrite and nitrate, garlic powder, white pepper, coriander and aniseed were bought from the local market.

Sausage preparation

The production of duck sausage was divided into two treatments: washed and unwashed. For washed samples, duck meat was washed with cold water at 1:1 ratio (v/w) of water to meat. A primary layer of water was removed and filtered through a commercial sieve. The water remaining in the washed sample was squeezed out using a cotton cloth and pressed using a screw press. Both treatments were then mixed with different amounts of carotino oil: A (80:0), B (77:3) and C (74:6). The formulation for preparing duck sausage is presented in Table 1. Other ingredients used in the formulation were water (5%), salt (2.5%), sugar (1%), monosodium glutamate (0.05%), sodium nitrite (0.01%), sodium nitrate (0.01%), wheat flour (3.43%), white pepper (2%), garlic powder (2%), coriander (2%) and aniseed (2%). All ingredients were mixed for 3 minutes using a high speed blender (Robot Coupe Blixer Grinder, France). The mixed meat was then stuffed into 2-cm cellulose casing then tied together and steamed until their internal temperatures reached 72°C. The samples were then immediately cooled in ice flakes for 15 minutes prior to being analyzed.

Table 1. Formulation for preparing duck sausage.

Ingredients	Formulation 1 (6% oil)	Formulation 2 (3% oil)	Formulation 3 (0% oil)
Ground Meat	74	77	80
Vegetable Oil	6	3	0
Water	5	5	5
Salt	2.5	2.5	2.5
Sugar	1	1	1
MSG	0.05	0.05	0.05
Sodium Nitrite	0.01	0.01	0.01
Sodium Nitrate	0.01	0.01	0.01
Wheat Flour	3.43	3.43	3.43
White Pepper	2	2	2
Garlic Powder	2	2	2
Coriander	2	2	2
Aniseed	2	2	2

Each value is in the form of percentage.

Proximate analysis

Moisture, protein, fat and ash contents were determined in accordance with standard AOAC methods [12]. Protein determination involved a Kjeldahl assay ($N \times 6.25$). Fat was determined by extracting samples in a Soxhlet apparatus using petroleum ether as a solvent. Moisture was quantified by oven-drying 10 g samples at 100-105°C overnight. Ash was determined after incineration in a furnace at 500-600°C.

Colour measurement

Samples were cooked at 90°C for 5 minutes and then sliced into pieces 4 mm thick [13]. The colour of cooked samples was measured using a colorimeter (Minolta CM 3500d, Japan). The colour reading includes lightness (L), redness (a) and yellowness (b).

Texture analysis and shear test

Samples were cooked at 90°C for 5 minutes and were uniformly cut into 1.5 cm pieces. Texture of samples were measured by using Texture Analyzer TA-XT2 (Stable Microsystem, UK), Compression Platen (SMS P/75) with a heavy duty platform and the following settings: load cell, 25 kg; speed, 3.0 mm/s; test speed, 1.0 mm/s; post test speed, 3.0 mm/s; prefixed strain, 75%; time before second compression, 2 s. The following parameters were determined: Hardness, cohesiveness, springiness, gumminess and chewiness. Shear test of the samples were done by using a Blade Set (HDP/BSW) with a heavy duty platform and the following settings: load cell, 25 kg; pre-test speed, 2.0 mm/s; test speed, 2.0 mm/s; post-test speed, 10.0 mm/s; target distance, 3.0 mm. The parameter to be determined was cutting force.

Scanning electron microscopy (SEM)

Microstructure of the sausages was measured according to the Andrés *et al.* [14] method. Small pieces of sausages of 0.5 cm in diameter and 0.2–0.3 cm thick were used for scanning electron microscopy (SEM) analysis. Samples were dehydrated in the freeze dryer overnight. Samples were mounted on aluminium stubs using a double-sided tape and then coated with a layer of gold (40–50 nm) under vacuum (sputtering), allowing surface and cross section visualization. Micrographs of the samples were obtained with scanning electron microscope (SEM 505, Philips, Eindhoven, The Netherlands).

Sensory evaluation

Sensory analyses were conducted by 30 panellists, all graduate students and faculty members at our University who were experienced in sensory evaluation of foods but had received no specific training relevant to these products. Panellists were asked to indicate how much they liked or disliked each product on a 7-point hedonic scale (7 = like extremely; 1 = dislike extremely) according to colour, odour, taste, texture and overall acceptability.

Statistical analysis

The trial was performed twice. Three formulations were analyzed and the results were expressed as mean values \pm SD. The sausage compositions and physicochemical characteristics were compared using one-way analyses of variance (ANOVA) and a Tukey test for multiple mean comparisons. Data were processed using SPSS version 17.0.

Results and Discussion

In this study, six different samples with different parameters were produced. The mean values of proximate analysis for duck sausage formulated with different oil added are presented in Table 2. An increase in oil level increased fat content and reduced moisture content significantly. Protein content was reduced but showed no significant difference ($P > 0.05$) as oil level increased. Washing increased the moisture content of the samples and reduced fat and protein content at the same time. Table 3 shows mean colour values of duck sausage. A higher oil level (6%) led to significantly higher lightness (L^*), redness (a^*) and yellowness (b^*) values. Sample lightness improved significantly after washing. Tables 4 and 5 show mean values for textural properties and sensory evaluation, respectively. Washing and the addition of oil reduced sample hardness but there were no significant differences ($P > 0.05$) in colour, odour, taste and overall acceptability. Figure 1 shows the micrograph of the unwashed and washed duck sausage. Samples with oil added were not used for the microstructure comparison as a result of the difficulty of observing pore structure.

According to Malaysian Food Regulations 1985 [15], the amount of actual meat in manufactured meat products like sausages should not be less than 65%. As a major ingredient in sausage, the percentage of meat used in the three formulations in this study were within the permissible limit. The moisture content of the duck sausage was significantly ($P < 0.05$) affected by washing and adding oil. Sausage produced with a washing treatment had a significantly higher moisture content, and increases in oil level were shown to decrease moisture. An increase in moisture content could be due to the water-binding capacity of added water plus moisture in the ingredients [16]. Hamm [17] reported that a greater amount of water could be held due to myofibrillar protein concentration in the washed meat, while fat and sarcoplasmic proteins were leached out. According to other studies, an increase in fat content would reduce the moisture content [18]. This result was similar to the result reported by Andrés *et al.* [14] where sausages with higher fat composition contained lower moisture.

The protein content for washed samples was lower than that of unwashed samples. This result correlated to the results reported by Perlo *et al.* [19], who reported that the protein content of mechanically deboned chicken meat was reduced from 13.6% to 9.4% after washing. This decrease in protein content could be due to the removal of water-soluble protein (sarcoplasmic) and undesirable water-soluble protein (myoglobin protein). The addition of oil to the formulation would also induce a decrease in the protein content of duck sausage.

Table 2. Proximate values of duck sausage formulated with different oil levels.

Sample	Moisture (%)	Protein (%)	Fat (%)	Ash (%)
UW-0	64.56 ± 0.28 ^a	12.57 ± 0.28 ^a	9.38 ± 0.24 ^e	5.10 ± 0.12 ^a
UW-3	56.65 ± 0.03 ^d	12.53 ± 0.37 ^a	13.68 ± 0.10 ^b	4.96 ± 0.10 ^a
UW-6	53.94 ± 0.55 ^e	12.48 ± 0.97 ^a	18.30 ± 0.32 ^a	4.09 ± 0.04 ^c
W-0	64.92 ± 0.30 ^a	11.81 ± 0.08 ^a	8.42 ± 0.12 ^f	4.54 ± 0.09 ^b
W-3	61.51 ± 0.08 ^b	11.63 ± 0.14 ^a	10.38 ± 0.19 ^d	4.18 ± 0.03 ^c
W-6	60.24 ± 0.06 ^c	10.77 ± 0.08 ^b	13.22 ± 0.21 ^c	3.84 ± 0.16 ^d

Value is the mean of triplicates

Means indicated with different superscript letters differ significantly ($P < 0.05$).

UW0, unwashed-no oil; UW3, unwashed-3% oil; UW6, unwashed-6% oil; W0, washed-no oil; W3, washed-3% oil; W6, washed-6% oil.

The washing process and adding oil affected the fat content of the samples. Fat content increased significantly when the amount of oil added was high and the amount of water in the sample was low. Crehan *et al.* [20] suggested that any increase in fat content may be attributed to moisture loss during processing. According to Cáceres *et al.* [21], fat content was reduced by increasing protein and/or water levels. Reduction in fat content can be explained by chemical interactions. Three types of interactions are involved in the meat products: protein:protein interaction (meat binding); protein:water interaction (water holding, or binding) and protein:fat interaction (fat binding). The relative importance of these interactions varies according to the nature of the product [8]. For washed meat, decreases in fat content were probably due to protein:water interactions. The interaction between protein and water was greater than those of interactions between protein and fat, leading to the release of fat from muscle tissue and a reduction in fat content. In this study, the fat values obtained were within the permissible limit of Malaysian Food Regulations 1985 [15], which specifies that fat content of all sausages shall not be more than 30%.

Results obtained agreed with those reported by Kumar and Aalbersberg [22], in which lower fat samples retained more ash. The loss of ash from meat samples was mainly a result of the loss of inorganic salts dissolved in the drips. For high fat samples, it could be true that decreased ash retention in the samples could be due to the loss of mineral elements drained with the melted fat into the drippings. Al-Najdawi and Abdullah [23] reported that high ash values are likely to be a result of bone particles incorporated into the mechanical deboned meat, especially Ca. Ash content in Table 2 was significantly reduced by washing, probably due to the removal of bone particles.

The colour of washed samples became lighter and less reddish after washing. At the same time, added oil increased the yellowness of the samples. The lightness of the samples was influenced by heme pigments, and the meat became lighter after the pigments were removed. Heme removal by washing is important because white meat is more valuable than dark meat [3]. Meat redness might also be affected by washing cycles; washing would reduce the concentration of the myoglobin that contributes to the redder colour. Moreover, yellowness decreased with fat reduction [20], and the lowest ($P < 0.05$) values were noted in the reduced-fat 0% samples.

Table 3. Colour values of duck sausage formulated with different oil levels.

Sample	L*	a*	b*
UW-0	51.36 ± 1.14 ^f	5.52 ± 0.23 ^d	17.30 ± 0.57 ^c
UW-3	51.96 ± 1.03 ^c	7.70 ± 0.11 ^b	20.14 ± 0.16 ^c
UW-6	52.68 ± 1.41 ^d	8.13 ± 0.17 ^a	21.81 ± 0.41 ^b
W-0	52.84 ± 1.38 ^c	5.75 ± 0.43 ^d	18.82 ± 0.44 ^d
W-3	55.15 ± 0.49 ^b	6.25 ± 0.30 ^c	21.56 ± 0.71 ^b
W-6	56.62 ± 0.55 ^a	6.39 ± 0.39 ^c	23.30 ± 0.89 ^a

Value is the mean of 5 replicates

Means indicated with different superscript letters differ significantly ($P < 0.05$).

UW0, unwashed-no oil; UW3, unwashed-3% oil; UW6, unwashed-6% oil; W0, washed-no oil; W3, washed-3% oil; W6, washed-6% oil.

Samples became less hard after washing and after the addition of oil. Samples with a high fat content exhibited lower breaking force values (Table 4). Fat in the sausages may have provided some lubrication [24]. Mittal and Barbut [25] also reported the same results. They noted that a decrease in fat produced an increase in sausage hardness. Different results were reported by Babji *et al.* [26]; they reported that the hardness of chicken meat frankfurters seemed to increase with fat content. This discrepancy is probably due to differences in composition and is a result of a different relationship between the components of the emulsion (fat, protein and water) and the consistency of the gel. Sample springiness showed no significant difference between samples, and the results obtained seemed not to be affected by oil addition and washing ($P > 0.05$). Similarly, cohesiveness, gumminess and chewiness were not significantly affected by washing and oil addition ($P < 0.05$). Cofrades *et al.* [27] found no relationship between sausage fat content (5%, 12% and 30%) and texture parameters. Because sausage hardness was affected by washing and oil addition, similar results were also obtained for shear force.

Table 4. Textural properties of duck sausage formulated with different oil levels.

Sample	Hardness (N)	Springiness (cm)	Cohesiveness	Gumminess (N/cm ²)	Chewiness (N/cm)	Shear force (N)
UW-0	55.78±0.78 ^b	0.59±0.45 ^a	0.24±0.02 ^c	13.24±0.17 ^{bc}	7.75±1.88 ^{bc}	2.67±0.44 ^a
UW-3	44.49±0.80 ^b	0.60±1.74 ^a	0.39±0.02 ^{ab}	17.06±0.27 ^{ab}	10.16±1.25 ^{ab}	2.45±0.30 ^b
UW-6	33.06±0.98 ^{bc}	0.51±1.70 ^a	0.44±0.13 ^a	15.65±0.84 ^{ab}	7.82±7.05 ^{ab}	2.33±0.24 ^a
W-0	46.17±0.49 ^a	0.61±0.42 ^a	0.31±0.01 ^{bc}	14.23±0.12 ^a	8.67±0.85 ^a	2.44±0.19 ^a
W-3	35.02±0.42 ^{bc}	0.60±0.20 ^a	0.33±0.01 ^{bc}	11.56±0.15 ^{bc}	6.89±1.82 ^{bc}	2.28±0.02 ^c
W-6	30.57±0.19 ^c	0.61±0.07 ^a	0.31±0.01 ^{bc}	9.47±0.07 ^c	5.76±0.89 ^c	2.10±0.02 ^c

Value is the mean of 5 replicates

Means indicated with different superscript letters differ significantly ($P < 0.05$).

UW0, unwashed-no oil; UW3, unwashed-3% oil; UW6, unwashed-6% oil; W0, washed-no oil; W3, washed-3% oil; W6, washed-6% oil.

Table 5 shows mean values of the sensory properties of low-fat duck sausage evaluated by 30 experienced panellists. Results obtained seemed to fluctuate and no significant differences ($P > 0.05$) were shown in the mean sensory scores for colour, odour, taste and overall acceptability. The washing treatment did not exert much influence on sensory score. The addition of oil to the

formulations at 3% and 6% also exhibited no particular trend, and the results seemed to fluctuate. According to Drewnowski [6], fat plays a major role in sensory properties because it makes a diet flavourful, varied and rich. But our results showed that fat had little effect on mean sensory score. Perhaps the combination of washing cycle and oil addition was not adequate in this case. Mean value scores for sensory properties (colour, odour, taste, texture and overall acceptability) were less than 5. According to Bhattacharyya *et al.* [4], duck sausage scored less with respect to flavour due to an inherent duck-like odour.

Table 5. Sensory evaluation of colour, odour, taste, texture and overall acceptability score on a 7-point hedonic scale (7= like extremely; 1= dislike extremely) of duck sausage with different oil levels.

Sample	Sensory properties				
	Mean values on hedonic scale				
	Colour	Odour	Taste	Texture	Overall Acceptability
UW-0	4.17±1.53 ^a	4.13±1.25 ^a	3.40±1.59 ^a	3.30±1.66 ^b	3.50±1.33 ^a
UW-3	4.23±1.45 ^a	4.27±1.20 ^a	3.90±1.63 ^a	3.97±1.13 ^{ab}	3.80±1.40 ^a
UW-6	3.93±1.60 ^a	4.17±1.37 ^a	4.03±1.69 ^a	4.60±1.57 ^a	3.77±1.45 ^a
W-0	4.23±1.45 ^a	4.20±1.21 ^a	3.87±1.81 ^a	4.10±1.52 ^{ab}	4.00±1.66 ^a
W-3	3.63±1.38 ^a	4.40±1.43 ^a	4.30±1.88 ^a	3.50±1.33 ^b	4.03±1.43 ^a
W-6	3.90±1.67 ^a	4.13±1.17 ^a	3.60±1.63 ^a	4.03±1.27 ^{ab}	3.67±1.60 ^a

Values is the mean of 30 panellists

Means indicated with different superscript letters differ significantly ($P < 0.05$).

UW0, unwashed-no oil; UW3, unwashed-3% oil; UW6, unwashed-6% oil; W0, washed-no oil; W3, washed-3% oil; W6, washed-6% oil.

Micrographs of washed samples without oil (W-0) and unwashed samples without oil (UW-0) are shown in A and B, respectively, in Figure 1. Overall, the pores of the washed samples were smaller than those of unwashed samples; this was probably due to excess water working with salt to help solubilise the meat myofibrillar protein that binds fat [28]. That is, the meat structure of washed samples was less porous than unwashed samples. During freeze drying, water droplets filling the pores would crystallize and subsequently sublimate, exposing the fine protein gel matrix [29].

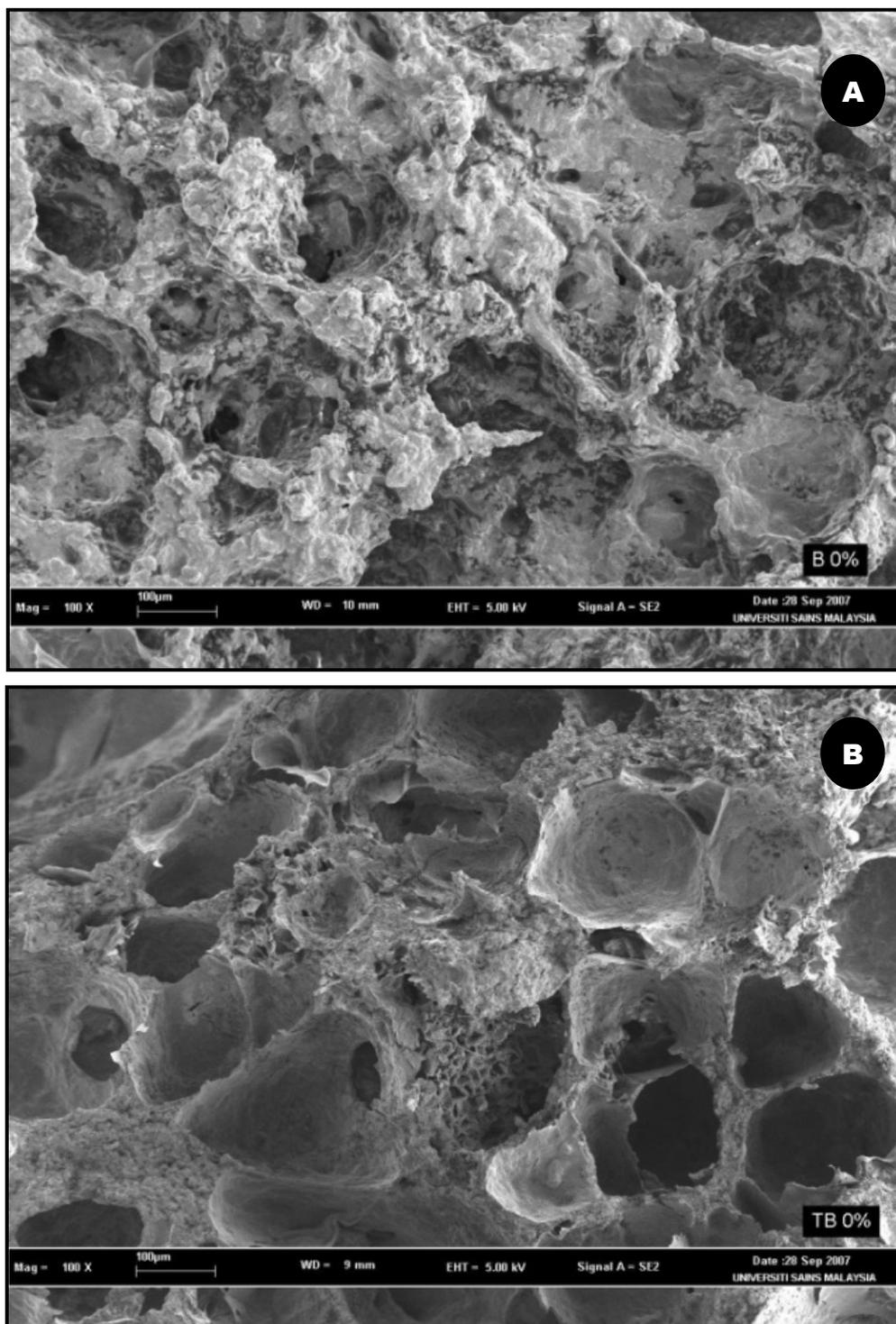


Figure 1. Scanning electron micrographs of low-fat duck sausage: (A) W0, washed sample without oil; (B) UW0, unwashed sample without oil. Based in 100× (bars= 100µm).

Conclusions

From this study, it is evident that different percentages of oil added to duck sausage formulations and washing treatments can influence the physicochemical properties and sensory qualities of low-fat duck sausage. As can be observed from the analysis performed in the present study, washing improved proximate compositions by lowering fat content and concentrating myofibrillar proteins, resulting in better gelling properties. Washing also increased lightness and reduced the redness of the duck sausage and resulted in a soft gel. Addition of oil to the duck sausage contributed to the formation of a stable emulsion, recovered lost fat and acted as a lubricant in producing softer texture. Both washing and oil added were still not adequate to increase the sensory properties of duck sausage. Future study could be carried out to improve sensory attributes of duck sausage, especially to remove the inherent duck-like odour and taste.

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