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RESEARCH ARTICLE ARAŞTIRMA MAKALESİ

DETERMINATION OF SOME FUNCTIONAL AND TECHNOLOGICAL PROPERTIES OF OCTOPUS (*Octopus vulgaris* C.), CALAMARY (*Illex coindetti* V.), MUSSEL (*Mytilus galloprovincialis* L.) AND CUTTLEFISH (*Sepia officinalis* L.) MEATS

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Abstract: In this research, emulsion properties of fresh octopus (*Octopus vulgaris* C.), calamary (*Illex coindetti* V.), mussel (*Mytilus galloprovincialis* L.) and cuttlefish (*Sepia officinalis* L.) were studied by using a model system. Some properties of meats from four different seafood species (octopus, calamary, mussel and cuttlefish), such as pH value, cooking loss (CL), water holding capacity (WHC), drip loss (DL) and various parametres of emulsion such as emulsion capacity (EC), emulsion stability (ES), oil separation from emulsion (SO), water separation from emulsion (SW), emulsion spesific gravity (ESG) were determined. Mussel muscle had the highest CL and DL while mussel had the lowest WHC ($p<0.01$). Cuttlefish muscle had the lowest CL and DL; however had the highest WHC value ($p<0.01$). Mean values of EC value of octopus, calamary, mussel and cuttlefish meats were determined to be 311.37, 329.38, 201.60 and 334.24 ml.oil/g. protein, respectively. The lowest ES value ($p<0.01$) was observed in the mussel meat among the other meats. The highest SO and SW values ($p<0.01$) were found in mussel meat. The emulsion specific gravities of the samples prepared with octopus, calamary, mussel and cuttlefish meats were determined to be 0.8752, 0.8793, 0.9500 and 0.8819 g/cm^3, respectively.

Keywords: Octopus, calamary, mussel, cuttlefish, emulsion properties, cooking loss, water holding capacity, drip loss

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Introduction

Meat is usually defined as the flesh (mainly muscles) and organs (for example, liver and kidneys) of animals (mammals, reptiles and amphibians) and birds (particularly poultry). Meat contains about 19 percent protein of excellent quality and iron that is well absorbed. The energy value of meat rises with the fat content. The fat in meat is fairly high in its content of saturated fatty acids and cholesterol. Meat also provides useful amounts of riboflavin and niacin, a little thiamine and small quantities of iron, zinc and vitamins A and C. Meat are nutritious and contain protein of high biological value. Animal protein sources are important in nutrition. Fish and seafoods, like meat, are valuable in the diet because they provide a high amount (usually 17 percent or more) of protein of high biological value, particularly sulphur-containing amino acids. Fish varies in fat content but generally has less fat than meat. Fish also provides thiamine, riboflavin, niacin, vitamin A, iron and calcium. It contains a small quantity of vitamin C if eaten fresh. Seafood meats have high nutritional and economic values and are suitable for processing. Therefore, better methods are necessary to use animal protein sources at maximum levels and make their usage more economical. Meat emulsions are economically very important for meat and food processing industry. Such emulsified meat products as salami and sausage have been consumed extensively all over the world.

The meat emulsion is a two-phase system consisting dispersion of solid (fat) in a liquid (water) in which the solid immiscible. In meat emulsions, discontinuous phase is fat, continuous phase is water. Emulsifying agent is the salt-soluble proteins (especially myofibrilar proteins). The emulsifying agent decreases the interfacial tension, reducing the energy which is necessary to make an emulsion. In emulsified meat products, proteins play an important role. Myofibrilllar (salt-soluble) proteins have high functionality in emulsification (Zorba, 1995). They affect water and oil holding ability, stability, specific gravity and other characteristic of emulsions. In order to determine these quality criteria in different emulsions, laboratory type model systems have been developed. Model system studies are economic, reproducible, require minimum time and give an idea about industrial process. Functional quality criteria of meat emulsions include emulsion capacity (EC), emulsion stability (ES), emulsion viscosity (EV), emulsion gel power, emulsion density and microscopic status (Gokalp et al., 1999; Zorba, 1995). Emulsion spesific gravity (ESG) is an important parameter for high amounts of fat-containing emulsions. The specific gravity of dispersted was lower than continous phase in an oil-in-water emulsion. This means that the density of an emulsion usually decreases with increasing oil content (McClements, 1999). The water holding capacity (WHC) is a more functional quality parameter. WHC is important regarding water and weight losses during storage, manufacturing, processing and preparation of the meat, for yield in meat products and for appreciation by the consumer. The level and the type of protein are important factors for water holding capacity, cooking loss and drip loss. The salt-soluble proteins have higher oil binding and water holding capacity than other proteins. At the isoelectric point, cooking loss (CL) is at a maximum, but WHC is at a minimum. The net charge of myosin and actomyosin are at a minimum at the isoelectric point. Low CL, drip loss (DL) and high WHC values are desired by industry and consumers.

Molluscs, one of the most important groups, are consumed all over the world, both as food and as feed supplement. Cephalopods including octopus, calamary and cuttlefish are among the important molluscs. Due to their nutritional value, cephalopod consumption has also shown an increase. Octopus, calamary and cuttlefish are rich in taste and have few inedible parts (Sikorski and Kolodziejska, 1986). Their muscles are rich in unsaturated fats, vitamins and minerals. According to FAO (2004), cephalopods contribute to 14% of the world fisheries. Mussels have an exceptional nutritional value making them ideal for the human diet. The mussels represent an important economic seafood for human consumption. Several species of the commonly-consumed molluscs in the Aegean Sea are the common octopus-*Octopus vulgaris*, red calamary-*Illex coindetti*, Mediterranean mussel-*Mytilus galloprovincialis* and common cuttlefish-*Sepia officinalis.*

In general, the protein content, composition and functional properties of some marine products have been reported (Kuznetsov et al., 1975; Erustun and Senturk, 1986; Kolodziejska et al., 1987; Bayizit et al., 2003; Celik et al., 2002; Thanonkaew et al., 2006; Vernocchi et al., 2007) but emulsion properties of octopus, calamary, mussel and cuttlefish muscle have not been well documented. These attributes (EC, ES, ESG) not only provide knowledge about the quality, but also give information about the suitability of these seafoods for emulsion type products. The objective of this study was to research various properties of octopus, calamary, mussel and cuttlefish meat in order to determine their suitability for technological processes.

Material and Methods

Meat sources used in this study were octopus (*Octopus vulgaris* C.), calamary (*Illex coindetti* V.), mussel (*Mytilus galloprovincialis* L.) and cuttlefish (*Sepia officinalis* L.) muscles. Octopus, calamary and cuttlefish were caught from Didim along Aegean Sea (Aydın, Turkey,) and the mussels were harvested from Izmir Bay (Turkey). The meat samples were brought to the Department of Food Engineering in Agriculture Faculty, Selcuk University, (Konya, Turkey) within 6-8 h under chilled conditions. The samples were cleaned, meat parts were separately ground through a 3.0-mm plate. Then, ground meats were separately mixed with a mixer in order to acquire homogenous batches. All samples were placed into the low density polyethylene bags. The bags containing the samples were kept at 4 °C during the analyses. The corn oil was obtained from local market and stored at room temperature in a dark environment. Analytical grade of chemicals were used at the analyses.

Proximate analyses and pH

Water (hot air oven), protein (Kjeldahl), fat (ether extraction) and ash (muffle furnace) contents of samples were determined using the methods as described in AOAC (2000). Moisture by drying a sample at 105°C to constant weight. For protein analyses factor 6.25 was used for conversion of nitrogen to crude protein. Ash content was determined by ashing at 550 °C for 5-6 h. The sample was homogenized (Waring Commercial Laboratory Blender-Waring Products Division U.S.A) in 100 ml of distilled water and pH was measured with a pH meter (WTW 315 I set model, Weilheim, Germany). The pH of minced meat plus salt-phosphate solutions and the formed emulsions were measured by a pH meter (Ockerman, 1985a).

Cooking loss (CL)

Cooking loss of samples were determined using the methods as described by Kondaiah et al. (1985). The meat sample (20g) was placed in a polyethlene bag and heated in a water bath at 80 °C for 20 min. The seperated water and oil was took away from the sample. The remained mass was weighed to determine cooking loss.

Water holding capacity (WHC)

Water holding capacities of samples were determined using the methods as described by Wardlaw et al. (1973). A meat sample (8 g) and 12 ml of 0.6M NaCl solution were put into a tube. The tubes were placed into a water bath (5 °C) for 15 min. Then, the tubes were centrifuged at 4100 rpm (5°C) for 15 min. The tubes were poured into a volumetric cylinder in order to collect the separated fluid. The WHC was calculated using the volume of separated fluid (ml).

Drip loss (DL)

Drip loss (DL) was determined according to Hu et al. (2008). The weighted meat cuts (2x3x5 cm) were put into a polyethylene bags. The bags were retained at 0-4°C for 168 h. The separated fluid was removed. The remained meat samples were weighted, again. The difference between the remained mass and separated fluid was used to determine drip loss.

Emulsion capacity (EC)

Emulsion capacity (EC) was determined by using a model system described by Ockerman (1985b). The model systems used are seen in Fig.1. The model systems were based on measuring electrical conductivity. At the emulsion break point, electrical conductivity was not present. The method utilised for end point determination was described by Webb et al. (1970). A solution of NaCl (2.5%) and K_2HPO_4 (0.50%) in water was prepared. To determine EC, 25 g of meat sample and 100 ml of cold salt-phosphate solution were placed into a blender jar and homogenised for 2 min at 13,000 rpm. 12.5 g of slurry and 37.5 ml of salt-phosphate solution were placed into a blender jar, and 50 ml of corn oil was added. To detect the break point of emulsions, electrodes were connected to an ohmmeter (YX-360 TRN Multitester Fuse & Diyote Protection, Sunwa, Moscow, Russia) with a millivolt recorder (Labsco Laboratory Supply Com. Ollmann & Co. KG, Louisville, KY). Oil was added at 0.8-1.0 ml/s. The blender rate was 13,000 rpm during emulsification. The burette was cooled with circulating water to maintain the oil at a constant temperature (11°C). The emulsion break point was detected when the ohm meter showed a sudden increase in resistance. At the break point, oil addition was stopped. The total amount of emulsified oil was calculated by considering the first 50 ml of oil added. EC was expressed as ml oil/ g protein.

Emulsion stability (ES)

Emulsion stability was determined by using a model system described by Ockerman (1985b). The centrifugation method was utilized for emulsion stability determination. In order to determine ES, 12.5 g of slurry and 37.5 ml of salt-phosphate solution were placed into a blender jar, and 50 ml of corn oil was added. All the process was done as EC determination, but this time, total amount of oil spent for each sample was 10 ml less than for emulsion capacity determination. 20 g of prepared emulsion was transferred into the cellulose nitrate test tubes. The tubes were placed in the water bath (Nüve, BM 402 model, Turkey) for 40 min at 80 °C. Then, they were centrifuged for 15 min at (5 °C) 4100 rpm (Nüve, NF 800R model, Turkey). The tubes were poured into a volumetric cylinder in order to collect the unbound oil and water. Emulsion stability was calculated by using the separated water (SW) and separated oil (SO).

Emulsion spesific gravity (ESG)

Emulsion spesific gravity was determined according to Kurt (1972). Emulsion and distilled water of 25 ml was placed into the pycnometer and weighted, respectively. It was calculated according to the following equation:

ESG (g/cm^3) = (The weight of emulsion)/(The weight of water) (4)

Statistical analysis

Each parameter was tested in triplicate samples with two replications. Collected data was subjected to analysis of variance (one way ANOVA) using MINITAB for Windows Release 13® (MINITAB, 2000). Duncan's multiple-range test was also used to determine the difference between mean values (Steel and Torrie, 1980).

SW (%) = The amount of water separated from emulsion (ml) x 5(1)

SO (%) = The amount of oil separated from emulsion (ml) x d x 5 (2)

(d: specific gravity of corn oil) (For the corn oil d = 0.91 g/ml)

ES (%) = 100 - (SW + SO)

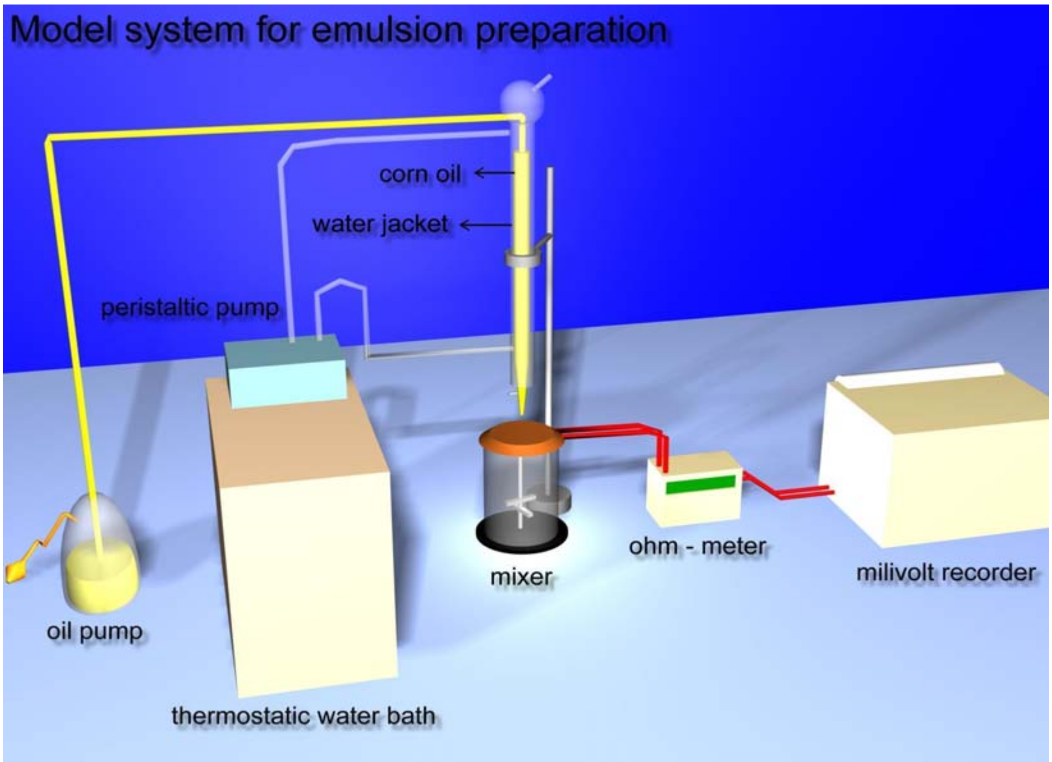

Figure 1. The model system for emulsion preparation.

Results and Discussion

Proximate analyses

The results shown in Table 1 demonstrate a significant (*p<0.01*) difference in proximate analyses of meat types. It was found that octopus meat had less solid as compared to the other meats. The amounts of moisture and protein content in calamary meat were similar to those in cuttlefish meat. The lowest protein content was found in mussel meat. This value was found lower in octopus than in calamary and cuttlefish muscles. No significant difference (*P>0.01*) was seen between protein content values of Calamary and Cuttlefish muscles. The highest fat content was found in cuttlefish muscle, while calamary muscle had the lowest fat content. Octopus muscle had the highest ash content among the other meats. The results of this study were consistent with those reported in the literature. It was reported that the composition of meat sources was influenced by species, fishing ground, age, body weight, seasonal changes in water temperature, feeding regimes and the other factors. Various parameters such as water temperature, feeding regimes, period of growing affect the biochemical composition, microbiological characteristic and meat productivity (Orban et al., 2002). The quality of the seafood depends on biological, chemical and sensory properties.

pH

The effect of species on the pH values were found to be significant (*p<0.01*). As seen in Table 2, the pH value of mussel muscle was the highest. On the other hand, octopus muscles had the lowest pH value. Celik et al. (2002) and Gokoglu et al. (1999) have found similar findings in their studies. Differences between pH values of the species might be due to the differences in buffering capacity of muscles. The result was in accordance with Pacheco-Aguilar et al. (2000) who reported that the changes in pH depended on a variety of factors such as species, fishing ground, feeding of the fish, storage temperature and buffering capacity of meat.

Changes in pH of meat, slurry and emulsion associated with meat sources are seen in Table 2. As seen in Table 2, addition of salt-phosphate solution increased the pH values of meats in the slurries which could be due to the presence of the alkaline K_2HPO_4 in salt-phosphate solution. Statistical analysis revealed that pH of the slurries and emulsions increased significantly (*p<0.01*). No statistically significant (*p>0.01*) differences were found between the pH values of octopus, calamary and cuttlefish slurries and the formed emulsions. The differences in pH value among meat sources were reduced by addition of salt-phosphate solution. Similarly the differences in pH value among meat sources were reduced by formation of emulsions. This might be due to using salt-phosphate solution, oil and conditions during emulsification.

Table 1. Proximate analyses results of meat sources

Analyses	*n*	Species			
		Octopus	Calamary	Mussel	Cuttlefish
Moisture (%)	6	81.10 ± 0.68^{a}	76.57 ± 1.19^{c}	79.51 ± 0.71^{b}	76.24 ± 0.28^{c}
Protein (%)	6	12.80 ± 0.38^{b}	15.38 ± 1.15^{a}	10.80 ± 1.17^{c}	14.53 ± 0.63^{a}
Fat (%)	6	1.14 ± 0.11^{ab}	0.97 ± 0.97^{b}	1.51 ± 1.51^{ab}	1.83 ± 1.83^{a}
Ash (%)	6	1.99 ± 0.12^{a}	1.50 ± 0.05^{bc}	1.16 ± 0.53^{c}	1.83 ± 0.18^{ab}

$^{a-c}$ Different letters within the same chopper indicate significant differences (*p<0.01*).

Table 2. The differences in pH values between meat sources, minced meat plus salt-phosphate solutions (slurry) and formed emulsions

Species	*n*	pH		
		Meat	Slurry	Emulsion
Octopus	6	6.28 ± 0.09^{c}	6.89 ± 0.08^{b}	7.39 ± 0.02^{b}
Calamary	6	6.49 ± 0.29^{bc}	6.86 ± 0.12^{b}	7.32 ± 0.14^{b}
Mussel	6	7.03 ± 0.09^{a}	7.39 ± 0.08^{a}	7.63 ± 0.02^{a}
Cuttlefish	6	6.73 ± 0.03^{b}	7.03 ± 0.09^{b}	7.40 ± 0.08^{b}

$^{a-c}$ Different letters within the same chopper indicate significant differences ($p<0.01$).

Water-holding capacity, cooking loss, drip loss

The differences in WHC, CL and DL among the kinds of meat are given in Table 3. Mussel muscles had the lowest; however, cuttlefish muscles had the highest WHC. CL of mussel muscles was the highest; however, cuttlefish muscles had the lowest CL value. Alike, DL of mussel muscles was the highest; however, cuttlefish muscles had the lowest DL value. No significant ($p>0.01$) differences were determined between the WHC, CL and DLvalues of octopus and calamary muscles.

The changes in the CL, WHC, DL with different meat species are seen in Table 3. The relationship between CL, WHC and DL was observed. WHC values were generally in accordance with CL and DL values. It can be seen in Table 3 that CL and DL values were remarkably high, but WHC value was low in mussel muscle.

Emulsion properties

Various parametres of emulsion such as emulsion capacity (EC), emulsion stability (ES), oil separation from emulsion (SO), water separation from emulsion (SW), emulsion spesific gravity (ESG) are given in Table 4. As seen in Table 4, for all parameters, significant differences ($p<0.01$) were found among the meat sources.

The EC is the maximum amount of oil that can be emulsified by proteins. It is strictly related to protein content and protein solubility (Kurt and Zorba, 2007). Haq et al. (1973) stated, the difference in EC could be due to the type of meat, protein conformation, protein fraction, physico-chemical properties and functional groups of the proteins. When the pH moves from the isoelectric point, the solubility of proteins increased (Zorba, 1995). Also, this may increase EC value of meat. Octopus, calamary and cuttlefish muscles had higher EC values when compared to mussel muscle. The lowest EC value was observed in the mussel muscle. It could be related to the amount of glycogen. Mussel muscle contains high amount of glycogen, and the EC value should be lower compared to the other meat samples. This result could be explained by the low protein content of mussel mussel and the differences in sturucture of proteins. Similar studies were performed by other researchers (Kaya, 1997; Bayrak, 1997; Karakaya, 1990; Zorba, 1990), and it might be concluded from those results that EC of cephalopods (octopus, caramary and cuttlefish) meats were generally higher than those of beef, lamb, goat and chicken meats. The EC values, in the present study of cephalopods were higher than those of shark meat (Mathew and Shamasundar, 2002), sardine muscle and pink perch meat (Sarma et al., 2000), similar to carp meat (Yapar et al., 2006). The difference could be related to the difference in composition and protein fraction of the meat studied. Besides, seafood meats contains lower amount of connective tissue and higher amount of myofibrillar protein, and the EC value of these meats should be higher as compared to that of red meats and poultry muscles (Gogus and Kolsarici, 1992). Emulsion capacity and myofibrilar protein concentration are highly correlated (Knipe, 2004; Sarma et al., 2000; Venugopal, 1997).

Table 3. Some technological properties of meat sources

Species	*n*	Technological properties		
		WHC (%)	CL (%)	DL (%)
Octopus	6	6.77 ± 1.28[b]	12.25 ± 1.28[b]	9.30 ± 1.26[b]
Calamary	6	5.73 ± 1.28[b]	14.20 ± 1.44[b]	10.29 ± 1.33[b]
Mussel	6	0.52 ± 1.28[c]	37.08 ± 1.55[a]	14.22 ± 1.43[a]
Cuttlefish	6	85.42 ± 3.79[a]	7.22 ± 1.67[c]	6.91 ± 1.01[c]

[a-c] Different letters within the same chopper indicate significant differences (*p<0.01*).
WHC: Water Holding Capacity CL: Cooking Loss DL: Drip Loss

Table 4. The mean and standart deviation values of the effect of meat source on some emulsion properties

Species	*n*	Emulsion Properties				
		EC	ES	SO	SW	ESG
Octopus	6	311.37 ± 23.48[a]	67.48 ± 2.20[b]	1.89 ± 0.93[b]	30.63 ± 1.31[b]	0.8752 ± 0.1333[b]
Calamary	6	329.38 ± 36.33[a]	73.83 ± 3.51[a]	2.84 ± 0.62[b]	23.33 ± 2.92[c]	0.8793 ± 0.0079[b]
Mussel	6	201.60 ± 40.58[b]	7.65 ± 1.76[c]	45.68 ± 3.17[a]	46.67 ± 4.66[a]	0.9500 ± 0.0098[a]
Cuttlefish	6	334.24 ± 29.68[a]	72.10 ± 0.69[a]	2.27 ± 0.00[b]	25.63 ± 0.69[c]	0.8819 ± 0.0116[b]

[a-c] Different letters within the same column indicate significant differences (*p<0.01*).
EC: Emulsion Capacity (ml.oil/g.protein) ES: Emulsion Stability (%) SO: Oil Separation From Emulsion (%)
SW: Water Separation From Emulsion ESG: Emulsion Spesific Gravity (g/cm^3)

ES is very important for the storage time of commercial products. The effect of meat source on the ES was statistically significant (*p<0.01*). The highest ES value among all samples studied was observed in calamary and cuttlefish muscles. Lower ES values was observed in mussel meat in comparison to other meats. The difference could be related to the difference in composition and protein fraction of the meats studied. The type of protein, ionic strength, pH and oil temperature could influence ES. It was seen that all emulsions prepared from mussel meat were broken during the heating process. This might be due to the difference in the hydrophilic and lipophilic characteristics of mussel proteins. This condition was consistent with the information reported by Elizalde et al. (1988), who stated that the stability of emulsions was related to the hydrophilic and lipophilic characteristics of the proteins. It was determined that there was a relationship between emulsion stability and protein content. The highest SO and SW values were found in mussel. This result could have been due to the effects of the protein content, the type of protein, the functional properties of protein fractions and pH of the meat. ES of octopus, calamary, cuttlefish and mussel meats were lower compared to the published data for meat from beef, sheep, goat, chicken, various offals, carp, pike (Atay, 2005; Bayrak, 1997; Karakaya, 1990; Zorba, 1990).

The emulsion specific gravity of sample prepared with octopus, calamary, mussel and cuttlefish meats were determined to be 0.8752, 0.8793, 0.9500 and 0.8819 g/cm^3, respectively. The highest ESG value was found in mussel muscle. However, no significant differences were found among the ESG values of octopus, calamary and cuttlefish meat. The differences might be due to the differences in chemical composition of muscle. In generally, increasing fat and water contents in the meat cause decreasing of specific gravity; increasing protein contents in the meat cause increasing of specific gravity . Besides, the ESG values of samples decreased with an increase in the amount of oil during the emulsification.

Conclusion

It was found that meat sources used in this study showed a significant (*p<0.01*) difference in proximate analyses. The amount of moisture and protein content in calamary meat is very similar to that in cuttlefish meat. The lowest protein content was found in mussel meat, and this value was found lower in octopus than in calamary and cuttlefish muscle. The highest fat content was found in cuttlefish muscle, while calamary muscle had the lowest fat content. Octopus muscle had the highest ash content among to the other meats.

EC of cephalopods (octopus, calamary and cuttlefish) meats were generally higher than mussel muscle. These properties make them appropriate for use in meat products.

An addition of salt-phosphate solution increased the pH values of meats in the slurries, which could be due to the presense of the alkaline K_2HPO_4 in salt-phosphate solution. The differences in pH value among meat sources was decreased by addition of salt-phosphate solution. The differences in pH values of meat sources decreased with formation of emulsions.

In this study, different meat sources were compared and it was concluded that mussel muscle were remarkably different from other muscles studied. The lowest values of EC and ES were found in mussel. Also, mussel had the highest SO, SW and ESG values. Cephalopods meats showed a higher EC compared with that of mussel meat. The use of cephalopods meats should result in considerable advantages in the production of further-processed comminuted meat products. Consequently, it is necessary to apply the results of this study in the industrial process.

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