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Influence of Different Heat Treatments on The Quality Characteristics of Edam Cheese

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IN this study, Edam cheese was produced from milk subjected to different heat treatments. In the production of Edam cheese, pasteurization (72°C/15 sec) and thermization (65°C/15 sec) were used in comparison to raw milk.The resultant cheese was ripened for 45 days and analyzed at 1, 15, 30 and 45 days intervals.The highest moisture content48.87% was determined in Edam cheese produced from pasteurized milk, while the lowest (45.55%) was observed in raw milk Edam cheese at the first stage of ripening. Edam cheeses produced either from pasteurized or thermized milk was characterized by lower fat and protein contents. The acidity of raw milk Edam cheese was the highest among all Edam cheese samples during ripening period. Ripening indices including WSN/TN (15.41, 13.20 and 14.58%) and NPN/TN (6.31, 5.78 and 6.17%) were determined and were comparable between raw, pasteurized and thermized milk Edam cheese respectively at the end of ripening. In addition, Edam cheeses from pasteurized or thermized milk characterized with lower hardness values than raw milk Edam cheese. Moreover, the applied heating of Edam cheese milk affected the microbial of Edam cheese samples and the level of proteolysis, lipolysis and subsequent liberation of free fatty acids and volatile compounds when compared to raw milk Edam cheese. Edam cheese produced from pasteurized milk had the higher sensorial scores particularly at the end of ripening period. Overall, Edam cheese manufactured with Pasteurized milk was higher in quality characteristic than others.

Keywords: Edam cheese, Pasteurization, Thermization, Free fatty acids, Volatile compounds.

Introduction

Cheese is the most common dairy product, which is manufactured from rawor pasteurized cow and buffalo's milk, but also from other species such as sheep and goats (Khattab et al., 2019). It differs from each other by their production method, ripening period, type of milk, texture, color, flavor, microbial loads and diversity and coagulation type (Kamimura et al., 2019). Different types of heat treatments can be used in the dairy industry such as thermization, heating, pasteurization, cooking, and sterilization. Heat treatments of milk are mostly applied to prevent pathogenic microorganisms, to improve stability of products during storage, to increase shelf life, affect the texture of the final product and enhancing the performance of following technological operations (Yoon et al., 2016). Utilization of raw milk for making cheese leads to cheeses with greater variability in comparison to pasteurized cheeseswhich is characterized by powerful and unique organoleptic profile which sometimes highly accepted by the consumers (Mituniewicz–Małek et al., 2019; Montel et al., 2014). In addition, several studies have shown that cheese produced from raw milk contains a broad diversity of microflora including lactic acid bacteria, which contribute for flavor production (Montel et al., 2014). On the other hand, using raw milk in cheese production is connected with the presence of *Listeria monocytogenes*, *Staphylococcus aureus*, *Campylobacter*, *Salmonella*, verocytotoxin-producing *Escherichia coli* and other pathogenic bacteria, which may risk the consumer health (Da Cunha-Neto et al., 2020;

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Verraes et al., 2015; Yoon et al., 2016). Also, the traditional cheese, which is made from raw milk, potentially has high healthy risks for consumers (Verraes et al., 2015).

However, heating cheese milk not only causes the destruction of heat-sensitive microorganisms (Buffa et al., 2004) and decreases the number of Propioni bacteria and heterofermentative lactobacilli, but also changes the catabolism of many organic acids, such as lactate and citrate, activates or deactivates the proenzymes and natural enzymes of milk, and changes the activity of lactic acid bacteria (Frau et al., 2014). The effect of temperature is also non-specific. It means that it increases the rate of adverse reactions and the possibility of growing the unwanted and contaminating microorganisms, such as mold, as well as it increases the rate of proteolysis (Martins et al., 2018). Despite developments in alternative technologies such as high-pressure processing and pulsed electric field technology for the destruction of microorganisms, heat treatment remains the method of choice in the dairy sector (Abdalla and Salih, 2020). Heat-treated milk at higher temperatures shows longer coagulation times and forms weaker and finer curd that retains more water, and these effects arise from the formation of complexes between denatured whey proteins and micellar *k*-casein, leading to alteration of the surface characteristics and interactions of casein micelles (Frau et al., 2014).

Thermization is planned to decrease the microflora of raw milk, reduce changes in quality of milk and procedure capability prior to conversion into product. Though thermization does not meet the supplies for pasteurization from the public health viewpoint, it is widely used for cheese milk and in amalgamation with other hurdles, e.g., cooking of the cheese curd, low pH, high salt in moisture, is probably satisfactory to render good-quality milk free of pathogens and food poisoning bacteria (Othman et al., 2012). In addition, milk pasteurization could be used as an efficient practice in cheese manufacturing to remove pathogenic or contaminant microorganisms (Giaccone et al., 2016; Ritota et al., 2017). Heat may affect the physicochemical propertiesof milk and changes its coagulation, proteolysis, and organoleptic properties of cheese product (Alegbeleye et al., 2018; Benfeldt and Sørensen, 2001). Studying these effects with the currency of thermal process has drawn the attention of many researchers in recent years. The effect of heating milk on increasing the yield of cheese produced is one of the significant benefits of this process that is related to retaining the coagulated serum proteins and more moisture in the final product (Buffa et al., 2004; Çakır and Çakmakçı, 2018).

Therefore, the objective of this study was to evaluate the influence of heat treatments on Physicochemical, volatile compound, free fatty acids, textural, microbiologicaland sensory characteristics of Edam cheese ripened for 45 days.

Materials and Methods

Materials

Fresh cow's milk (10.60% dry matter, 3.01% fat, 3.14% protein, 3.67% lactose, 0.78% ash,6.61 pH and 0.19% acidity) was supplied by dairy industry unit, Faculty of Agriculture, Fayoum University, Fayoum, Egypt. The starter cultures (FD-DVS CHN-11, mesophilic aromatic culture) consist of *Lactococcus lactis* subsp. *cremoris*, *Leuconostoc*, *Lactococcus lactis* subsp. *lactis*, *Lactococcus lactis* subsp. *lactis* biovar *diacetylactis*) was supplied by MIFAD Company for food additives, Cairo, Egypt. Rennet powder (CHY-MAX, 2280 IMCU/ml) was obtained from Ch. Hansen Lab., Denmark. Commercial pure fine grade salt (NaCl) was obtained from Emisal Company, Fayoum, Egypt. Calcium chloride (Food quality grade) was obtained from EL-Nasr Company, Cairo, Egypt. Chemicals and reagents used in this study were analytical grade and obtained from El- Nasser, Merck and Sigma Companies.

Methods

Manufacture of Edam cheese

Edam cheese was manufactured according to the method used by Hoffmann et al. (2020) with some modification. Fresh milk was divided into three equal portions; the first portion was left as raw milk (control) without heatingwhile the second portion was thermized to 65ºC /15 sec (T1) and the third portion was pasteurized to 72ºC/15 sec (T2). Milk was cooled immediately to 32 ºC (in T1 and T2), and reached 32 ºC in control. Then treatments were placed in cheese vat and inoculated with FD-DVS CHN-11 starter culture (1.00%)and left for 30 min to increase acidity by 0.01%. Then, 0.02% $CaCl_2$ was addedandmilk was renneted by (3g/100 kg milk). The curd was cut and settled for 10 minutes without agitation. Scalding started and continued for 30 min reaching

37ºC. Whey was drained off and the curd was washed with warm water. The curd was pressed then brine salted (16 % brine solution) for 48 hr at 12ºC then dried, coated and ripened for 45 days. Cheese samples were taken for all treatments at fresh, 15,30,45 days for physicochemical, microbiological, and sensorial analysis,and at 45 days for volatile compounds,free fatty acids and textural profile analysis. On sampling, the rind was removed from each cheese and about 100 g of reprehensive samples was grated to obtain a homogeneoussample for the further analysis.

Physicochemical analysis

Cheese samples were analyzed in triplicate during 45 days of ripening for titratable acidity by the titration methods, moisture by drying oven at 100ºC for 3-4 hr, Protein by Kjeldahl method, fat by Gerber method, water soluble nitrogen (WSN), non-protein nitrogen (NPN) contents by Kjeldahl method as described by (AOAC, 2005),ash using a muffle furnace. pH values were measured by using pH meter (Model Kent EIL 7020, UK).

Volatile compounds

Gas Chromatographic (GC) Analysis was performed by using Hewlett-Packard model 5890 equipped with a flame ionization detector (FID). A fused silica capillary column DB-5 (60mx0.32 mm id,) was used. The oven temperature was maintained initially at 50°C for 5 min, and then programmed from 50 to 250°C at a rate of 4°C/ min. Helium was used as the carrier gas, at flow rate of 1.1 ml/min. The injector and detector temperatures were 220 and 250°C, respectively. The retention indices (Kovats index) of the separated volatile components were calculated using hydrocarbons (C8-C22, Aldrich Co.) as references. The analysis was carried out by using a coupled gas chromatography Hewlett-Packard model (5890)/ mass spectrometryHewlett-Packard MS (5970). The ionization voltage was 70 eV, mass range m/z 39-400 a.m.u. The GC condition was carried out as mentioned above. The isolated peaks were identified by matching with data from the library of mass spectra (National Institute of Standard and Technology) and compared with those of authentic compounds and published data (Adams,2007). The quantitative determination was carried out based on peak area integration. Values expressed as area percentage of peaks.

Free fatty acids

To extract fat, the cheese samples were dried at 40ºC for 12 hr in hot air oven, grounded and cheese sample weighing 8 g were mixed with n-hexane as a solvent for extraction of oil. The solvent was evaporated in hot air oven and the extracted oil was converted to fatty acid methyl esters according to (AOAC, 2019). In brief, 50 mg extracted fat was placed in the screw capped test tube, 2 mL methanolic HCl was added, mixed for 1 min, heating at 100°C for 1 hr, tubes were cooled down to room temperature, 2 ml n-hexane, 2 mL distilled were added, vortex at 2200 rpm for 2 min, settled for 30 min. The supernatant was collected and I uL of supernatant was injected into GC-MS (79890-A Agilent, USA) equipped with a Mass Selective Detector (MSD) at a 10:1 split and a 5 min solvent delay. Analyses were performed using helium (1mL/min flow rate) as carrier gas and the oven was set for 5°C/min ramp from 60°C to a final temperature of 240°C, with a 42 min run time. The MS was set the scan mode and data were collected from 40-400 mass-to-charge ratio and fatty acid peaks were identified and quantified by FAM 37 internal standard (Sigma Aldrich, UK) and expressed as g/100g lipids.

Textural profile analysis

The hardness (N), cohesiveness (~), springiness (mm), gumminess (N) and chewiness (N.mm) of Edamcheese samples were evaluated at room temperature (20°C) using a Texture Analyzer (Model CT310K Texture Analyzer, USA) according to(Gunasekaran and Ak, 2002).

Microbiological analysis

Edam cheese samples were homogenized (1:10) with peptone water (10 g/L casein peptone, 5 g/L NaCl and 20 g/L trisodium citrate dehydrate with pH 7.0) at 40ºC. The homogenate was then serially diluted with (8 g/L NaCl, 1 g/L casein peptone, pH 7.2). The dilutions were plated on M17 agar for cultivation of *lactococci*, Nutrient agar for total viable count, Potato Dextrose Agar (PDA) for the enumeration of yeasts and molds and MacConkey Agar for the enumeration of *Escherichia coli*.Spores were enumerated on nutrient agar and Mannitol salt agar was used for the enumeration of *Staphlococcus aureus.* The M17 agar plates at 30ºC for 48 hr, and PDA agar plates at 25ºC for 72 hr, nutrient agar plates for spores at 37 ºC for 72 hr, Mannitol salt agar at 37ºC for 48 hand MacConkey Agar plates at 37 ºC for 24-48 hr. Three replicates were performed for each sample. Microbiological analysis were performed according to APHA (2015).

Sensory evaluation

The sensory characteristics of Edam cheese samples, according to the method used by (Hamdy et al., 2021), were assessed by twentyexperienced panelists. Randomly numbered samples were presented to panelists in individual trays. The panelists were asked to evaluate Edam cheese samples using a nine point hedonic scale test. The scale consisted of taste, texture, appearance, smell and overall acceptability.

Statistical analysis

Data were recorded in three replicates and processed by one way ANOVA with SPSS Statistics 24 (IBM, USA) and comparing means at $p \leq 0.05$ by the least significant difference test (LSD). The results were expressed as means ± standard deviation.

Results and Discussion

Effect of heat treatments of milk on the coagulation time and cheese yield

Different heat treatments of cheese milk affected the coagulation time and cheese yield of Edam cheeses as seen in Table 1. The longer coagulation time (75 min) was obtained with cheese milk treated with 72°C/15 sec (T2), while the shorter coagulation time (30 min) was obtained with raw cheese milk (C) and the thermized cheese milk (T2) took 45 min for coagulation. In addition, the cheese yield was 12, 12.5 and 13.5 kg/ 100 L of cheese milk in C, T1 and T2 respectively. These results were in line with (Tadjine et al., 2019) who reported that the actual cheese yield of pasteurized milk was higher than in raw milk. The coagulation time and the actual cheese yield is depended mainly on the quality of milk and the corresponding processes from which the heat treatment of cheese milk (Tadjine et al., 2019). Similar findings were found in cheddar cheese (San Martín-González et al., 2007) and in Mashanza cheese (Salwa and Galal, 2002). The increased yield in thermized and pasteurized milk is probably due to the higher moisture retention in pasteurized and thermized milk leading to high recovery of whey proteins and the soluble solids (Tadjine et al., 2019). The higher the temperature, the higher the cheese yield due to the more moisture, whey solids and salt retention in cheese curd which was in consistent with (Farkye, 2004). The results of coagulation time is consistent with (Singh and Waungana, 2001) who revealed that cheese milk heated at higher temperatures higher than pasteurized temperature showed longer coagulation time and the curd becomes weaker and finer retaining more water. This was mainly due to the formation of complexes betweendenatured whey proteins and micellar *k*-casein, which might alter the surface characteristics and casein micelles interactions(Singh and Waungana, 2001). In addition, Ismailb et al. (2004) reported that heating cow's and buffalo's milk to temperature higher than 72 °C increased rennet coagulation time and decreased curd tension and syneresis values. Abd El-Gawad and Ahmed (2011) reported that heat treatment might increase the rennet clotting time in cheese making due to the formation of a complex between *k*-casein and β- lactoglobulin and this depends on the severity of heat treatment. On the other hand, it was found that heat treatment led to an increase in cheese yield due to the higher moisture retention in cheese network. These results were in line with Awad, (2006); De Candia et al., (2007); Vélez et al., (2010). In addition, Miloradovic et al. (2017) produced soft cheese from milk subjected to different heat treatments. High heat treatment of cheese milk led to an increase in cheese yield. It also affected the composition of cheese by retaining higher levels of water, fat and whey proteins.

Physicochemical composition

As seen in Table 2, the results showed that pH values were not significantly different ($P \leq 0.05$) at the first period of ripening among all Edam cheese samples till the 15th day of ripening. The average pH of raw Edam cheese was 5.57 and it was comparable to experimental Edam cheese produced from pasteurized or thermized milk. The pH decreased progressively in all Edam cheese samples during the ripening period of 6 weeks. The initial pH in the experimental cheese were 5.57, 5.67 and 5.63 in C, T1 and T3 respectively which reduced to 5.17, 5.23 and 5.13 for the same treatments respectively at the end of ripening period. During ripening, variations in pH values were not significant ($p \leq 0.05$) among different experimental cheeses. The results were in line with (Othman et al., 2012) on Cantal cheese produced from raw, pasteurized and thermized milk, reported that pH values were higher in heat treated cheeses than pH of raw cheeses with non-significant differences among experimental cheeses. This might be attributed to the higher microbial load in raw milk and the metabolism of lactic acid and subsequent lowering pH values compared to heat treated milks (Law and Tamime, 2011).

On the other hand, higher acidity was observed

in Edam cheese produced from raw milk (0.85%) which was comparable to the acidity of Edam cheese produced from thermized milk (0.81%) and Edam cheese produced from pasteurized milk (0.82%) at the first stage of ripening. The lowest acidity (0.81%) was obtained in thermized Edam cheese. The acidity increased progressively in all Edam cheese samples during ripening period. At the end of ripening period, the higher acidity was determined in raw Edam cheese followed by Edam cheese produced from pasteurized milk then Edam cheese from thermized milk. There were significant differences ($P \leq 0.05$) in acidity values between all Edam cheeses at the late stages of ripening. These results were in agreement with (Sert et al., 2014) in Tulum cheese, who observed that titratable acidity in cheese produced from raw milk was higher than acidity of cheese produced from pasteurized milk. The higher acidity in Edam cheese produced from raw milk might be due to the activity of natural microflora and the activity of indigenous enzymes in raw milk (Bayar and Özrenk, 2011).

The moisture content of all Edam cheese samples decreased progressively during the ripening period (Table 2) due to the evaporation (Vélez et al., 2010). Moisture in the experimental Edam cheese produced from pasteurized milk was higher than that in Edam cheese produced with raw milk and Edam cheese produced from thermized milkduring the ripening period. There were significant differences ($p \leq 0.05$) in moisture content among all Edam cheese samples. The highest moisture content (48.87%) was observed in Edam cheese produced from pasteurized milk, while the lowest moisture content (45.55%) was obtained with Edam cheese produced with raw milk. These values reduced to 44.61% and 41.12% for Edam cheese from pasteurized milk and Edam cheese from raw milk respectively after 6 weeks of ripening.These results were in agreement with (Othman et al., 2012). The increase in moisture content in experimental Edam cheese might be due to the application of heat treatments and the retention of moisture. In addition, the higher moisture content in Edam cheese from pasteurized milk could be explained by the presence of whey proteins holding into cheese matrix as reported by Aljewicz et al., (2014) and Sabikhi et al. (2014). On the other hand, pasteurization affected the retention of water into cheese matrix. Moreover, (Tadjine et al., 2019) studied the effect of pasteurization on cheese milk in the production of semi hard cheese and reported higher retention of fats and proteins in cheese milk subjected to pasteurization leading to higher retention of water compared to cheese produced from raw milk. These results were in line with Salwa and Galal (2002) who reported that heat treated and pasteurized milk cheeses revealed higher moisture than raw milk cheeses.

The results revealed that heat treatment had a significant effect ($p \leq 0.05$) on the fat and protein percentages of all Edam cheese samples. The highest fat percentage 25.57% was recorded in Edam cheese from raw milk, while the lowest fat percentage 25.23% was determined in pasteurized milk Edam cheese at the first stage of ripening. This might be due to the increasing dry matter content in Edam cheese produced from raw milk. Fat and protein of all Edam cheese samples increased gradually till the end of ripening period and this might be due to the loss of water from cheese loaves during ripening. These results were in line with Othman et al. (2012) who reported a decrease in fat and protein content in heated milk cheeses than in raw cheese due to the increase in moisture leading to lower dry matter in cheese matrix.

TABLE 1. Coagulation time and cheese yield of Edam cheese with different heat treatments

Property	Raw milk	Edam cheese produced from	
		Thermized milk (65 °C/15 sec.)	Pasteurized milk (72 °C/15 sec.)
Coagulation time (min)	**30**	**45**	**75**
Cheese yield (kg/100 L)	**12**	**12.5**	**13.5**

TABLE 2. Physicochemical composition of Edam with different heat treatments

Property	Ripening period (days)	Edam cheese produced from		
		Raw milk	Thermized milk (65 °C/15 sec.)	Pasteurized milk (72 °C/15 sec.)
pH	1	5.57±0.06a	5.67±0.06a	5.63±0.06a
	15	5.43±0.06a	5.47±0.06a	5.40±0.00a
	30	5.23±0.06ab	5.33±0.06a	5.20±0.00b
	45	5.17±0.06a	5.23±0.06a	5.13±0.06a
Acidity (%)	1	0.85±0.03a	0.81±0.02a	0.82±0.02a
	15	0.96±0.03a	0.87±0.02b	0.90±0.02b
	30	1.13±0.02a	0.95±0.03b	1.02±0.07b
	45	1.27±0.03a	1.11±0.02c	1.19±0.02b
Moisture (%)	1	45.55±0.08c	47.17±0.05b	48.87±0.06a
	15	43.68±0.08c	45.24±0.07b	47.17±0.06a
	30	42.38±0.03c	43.67±0.07b	45.74±0.06a
	45	41.12±0.05c	42.53±0.03b	44.61±0.02a
Fat (%)	1	25.57±0.06a	25.33±0.06b	25.23±0.06b
	15	26.70±0.10a	26.37±0.06b	26.20±0.00c
	30	27.63±0.012a	27.47±0.06b	27.27±0.06c
	45	28.53±0.06a	28.40±0.00b	28.13±0.06c
Protein (%)	1	21.40±0.05a	19.79±0.04c	20.71±0.06b
	15	22.49±0.20a	20.61±0.04c	21.51±0.06 b
	30	23.05±0.07a	21.51±0.07c	22.22±0.06b
	45	23.60±0.06a	22.08±0.05c	22.76±0.06b
Fat/DM (%)	1	46.95±0.10c	47.96±0.10b	49.35±0.20a
	15	47.41±0.20c	48.15±0.10b	49.60±0.05 a
	30	47.96±0.20c	48.76±0.10b	50.25±0.05a
	45	48.46±0.13c	49.42±0.02b	50.79±0.09a
Ash (%)	1	2.84±0.03c	2.96±0.03b	3.07±0.02a
	15	2.94±0.05b	3.05±0.03a	3.11±0.02a
	30	3.08±0.02b	3.11±0.02b	3.18±0.02a
	45	3.21±0.03c	3.32±0.03b	3.38±0.03a

Data expressed as means±standard deviation

Different letters in the same row indicate significant differences ($P \leq 0.05$)

On the other hand, Fat/DM and ash were higher in Edam cheese produced from pasteurized milk than thermized and raw Edam cheeses. These values increased in all Edam cheese samples during the ripening period due to the increasing dry matter by losing water by evaporation in the ripening chamber. The highest ash content (3.07%) was obtained in T2, while the lowest ash content (2.84%) was determined in raw Edam cheese at the first stage of ripening period.

Ripening indices

The average SN/TN and NPN/TN fractions in raw Edam cheese were comparable to the experimental cheese produced from pasteurized and thermized milk (Table 3). The lowest level of SN/TN (7.85%) and NPN/TN (2.15%) was observed in thermized Edam cheese, while the highest level of SN/TN (8.65%) and NPN/TN (2.48%) was recorded with raw Edam cheese at the first day of ripening period. The fraction of SN/ TN and NPN/TN in all cheese samples increased progressively until the end of ripening period. The increase in SN/TN and NPN/TN fractions were higher in pasteurized Edam cheese than in the thermized Edam cheese. At the end of ripening period, the fraction SN/TN (15.41%) in raw Edam cheese was comparable to SN/TN in Edam cheese produced from pasteurized milk, while Edam cheese from thermized milk recorded 13.20%. The higher levels of SN/TN and NPN/TN were correlated to the growth of LAB and NSLAB cultures and their enzymes and the degradation of β-casein (Azarnia et al.,2010).

In addition, the higher SN/TN fraction of Edam cheese after brining was related to the action of residual coagulant, proteinases from milk and somatic cells, plasmin activity and microbial protease. Moreover, the higher moisture and acidity activate the action of chymosin on α S1-casein (Hinz et al., 2012), leading to the increase of SN/TN fraction after brining beside the higher increase of SN/TN occurring at the end of ripening period due to the bacterial proteinases, which are extensively released via lysis of their source microflora (Aljewicz et al., 2014). The SN fraction formation in Edam cheese is mainly dependent on chymosin activity and the enzyme activity of starter bacteria. In addition, the higher proteolysis is related to the higher moisture content and the initially lower salt (Düsterhöft et al., 2018).

Textural profile analysis

The parameters of texture profile analysis are shown in Table 4. The heat treatments of cheese milk affected those parameters. Raw Edam cheese was the hardest cheese (28.69) among all experimental Edam cheese, while Edam cheese produced from pasteurized milk had the lowest hardness value (15.11). Hardness was affected by the type and severity of heat treatment in experimental Edam cheeses. This was related to the higher moisture retention in protein matrix of Edam cheese with produced from pasteurized milk which make cheese less elastic and more likely to change shape when pressed (Fox et al., 2017a). In addition, pasteurization of cheese milk might reduce the hardness of cheese due to the retention of moisture in cheese matrix (Awad, 2006). The same trend was observed with gumminess and chewiness values which may be attributed to the higher moisture retention in cheese. On the other hand, springiness and cohesiveness values were comparable in raw Edam cheese and Edam cheese produced from pasteurized milk. These findings were comparable to those obtained by Awad (2006); Düsterhöft et al., (2018); Květoslava et al., (2021).

Flavor compounds

The flavour compounds of different Edam cheese samples produced from milk subjected to different heat treatments are illustrated in Table 5. There were different profiles of flavor compounds presented in Edam cheeses. These could be related to the effect of such heat treatments on the behavior of cheese milk during processing of Edam cheese till the ripened cheese. The flavor profile of Edam cheese produced from thermized milk and pasteurized milk was comparable to the profile of Edam cheese produced from raw milk. It was reported that the volatile compounds such as alcohols, ketones, aldehydes, fatty acids, lactones, esters and terpenes are responsible for the flavor of cheese (Fox et al., 2017b). The occurring of these compounds arise at the earlier stage of production and accumulate in the ripened cheese through different metabolic pathways including proteolysis, lipolysis and lactose hydrolysis (McSweeney, 2004; Vítová et al., 2011). The formation of volatile substances in Edam cheese might be affected by the mesophilic starter cultures, technological practices, salt and the ripening conditions (Van Leuven et al., 2008). Edam cheese proteins are hydrolyzed enzymatically to large, medium and subsequent

small peptides and free amino acids which are the nutritional source of lactic acid bacteria (Fox et al., 2017b), such amino acids converted later to amines, alcohols, fatty acids, esters, carbonyl and sulfur compounds which contribute mainly to the flavor of Edam cheese (McSweeneyet al., 2006; Nhuchet al., 2008). Our findings were in line with the flavor compounds of Edam cheese detected by (Vítová et al., 2011). Different flavor compounds were detected such as Benzene, 1,2,4-trimethyl- , Benzene, 1-ethyl-3-methyl-, Mesitylene, Benzene, 1,2,3-trimethyl-, Benzene, 1,3-diethyl- , Benzene, 4-ethyl-1,2-dimethyl-, p-Cymene, (S,E)-2,5-Dimethyl-4-vinylhexa-2,5-dien-1-yl acetate, Octanoic acid, TMS derivative, 1-Dodecene, Decanoic acid, trimethylsilyl ester, Thiosulfuric acid (H2S2O3), S-(2-aminoethyl) ester, Methoxyacetic acid, 2-tetradecyl ester, 1-Hexadecanol, 2-methyl-, Dodecanoic acid, 3-hydroxy-, E-9-Tetradecenoic acid, Z-10-Pentadecen-1-ol, 1-Dodecanol, 3,7,11-trimethyl- and Hexadecane, 1,1-bis(dodecyloxy)-. These compounds appeared mainly at the later stages of ripening which contributed to the flavor intensity of Edam cheese that marked by panelists during the sensory evaluation.

TABLE 3. Ripening indices of Edam with different heat treatments

Property	Ripening period (days)	Edam cheese produced from		
		Raw milk	Thermized milk (65 °C/15 sec.)	Pasteurized milk (72 °C/15 sec.)
SN/TN (%)	1	8.65±0.60a	7.85±0.70a	8.22±0.50a
	15	10.31±0.40a	9.08±0.50b	10.18±0.40a
	30	13.38±0.70a	11.86±0.30b	12.16±0.20b
	45	15.41±0.60a	13.20±0.90b	14.58±0.30a
NPN/TN (%)	1	2.48±0.20a	2.15±0.20a	2.26±0.20a
	15	3.40±0.40a	2.89±0.50a	3.26±0.40a
	30	4.71±0.30a	3.86±0.30b	4.40±0.20a
	45	6.31±0.40a	5.78±0.30b	6.17±0.30a

Data expressed as means±standard deviation

Different letters in the same row indicate significant differences ($P \leq 0.05$)

TABLE 4. Rheological properties of Edam cheese with different heat treatments

Property	Edam cheese produced from		
	Raw milk	Thermized milk (65 °C/15 sec.)	Pasteurized milk (72 °C/15 sec.)
Hardness (N)	28.69	22.27	15.11
Cohesiveness (B/A area)	0.43	0.36	0.60
Gumminess (N)	12.48	7.92	9.06
Chewiness (N.mm)	9.93	6.96	7.93
Springiness (mm)	0.80	0.88	0.87

Values are presented as means of one determination for clarity

TABLE 5. Flavour compounds of Edam cheese produced with different heat treatments

Compound	Raw milk	Edam cheese produced from	
		Thermized milk (65 °C/15 sec.)	Pasteurized milk (72 °C/15 sec.)
Benzene, 1,2,4-trimethyl-	8.91	2.57	4.85
Benzene, 1-ethyl-3-methyl-	3.35	1.7	3.22
Mesitylene	30.69	12.78	22.77
Benzene, 1,2,3-trimethyl-	13.91	6.64	9.82
Benzene, 1,3-diethyl-	7.27	1.27	2.09
Benzene, 1,2-diethyl-	--	4.11	--
Benzene, 1,4-diethyl-	--	--	4.3
Benzene, 4-ethyl-1,2-dimethyl-	4.04	2.5	2.5
p-Cymene	5.1	1.86	0.87
(S,E)-2,5-Dimethyl-4-vinylhexa-2,5-dien-1-yl acetate	3.51	--	--
Oxirane, octyl-	--	2.19	5.47
1-Dodecene	3.92	5.03	5.18
Octanoic acid, TMS derivative	1.48	6.42	3.83
Methoxyacetic acid, 4-tridecyl ester		1.47	2.85
2-Myristynoyl pantetheine	--	--	0.61
Decanoic acid, trimethylsilyl ester	3.07	--	--
Thiosulfuric acid (H2S2O3), S-(2-amino-ethyl) ester	1.62	--	0.8
Methoxyacetic acid, 2-tetradecyl ester	1.65	1.93	2.57
1-Hexadecanol, 2-methyl-	1.48	--	--
2H-Pyran, tetrahydro-2-(12-pentadecy-nyloxy)-	--	2.4	1.81
Decanoic acid, TMS derivative	--	1.19	--
Decane, 2-methyl-	--	--	1.24
Dodecanoic acid, 3-hydroxy-	1.43	1.14	0.68
E-9-Tetradecenoic acid	1.48	3.77	1.48
2,4-Di-tert-butylphenol	--	2.33	1.79
Dodecane, 1-fluoro-	--	--	1.41
Z-10-Pentadecen-1-ol	1.52	4.7	2.72
10-Undecenoic acid, octyl ester	--	1.63	0.92
1-Dodecanol, 3,7,11-trimethyl-	1.82	5.06	3.38
Hexadecane, 1,1-bis(dodecyloxy)-	3.74	11.28	6.72
9-Octadecenal, (Z)-	--	5.23	2.61
1-Hexadecanol, 2-methyl-	--	3.03	2.09
9-Octadecenoic acid (Z)-	--	3.67	1.38

Free fatty acids

The free fatty acid profile of different Edam cheese samples are presented in Table 6. It can be seen that Edam cheese produced from pasteurized and thermized milk had a comparable fatty acid profile to Edam cheese produced from raw milk. The fatty acid profile contained Butyric acid, Caproic acid, Caprylic acid, Capric acid, Lauric acid, Myristic acid, Palmitic acid, Stearic acid, Elaidic acid, Linoleic acid, Coprostan-3β-ol, Icosapentaenoic acid Linolenic acid and Arachidonic acid. The formation of free fatty acids in Edam cheese samples contributed to the flavor intensity of ripened cheese. Different enzymatic actions were responsible for the release of such fatty acids depending on the microflora of cheese and their enzymatic activities (Fox et al., 2017b). These findings were in agreement with (Awad, 2006) who reported a comparable fatty acid profile of Ras cheese produced from raw and pasteurized milk. It was reported that fatty acids play and important role in the flavor of cheese and its formation depended on the used starter culture, manufacturing technology, rennet and ripening time (Collins et al., 2003). The applied heat treatments affected the fatty acid profile of Edam cheese by affecting the enzymatic states of cheese milk, microbiota of cheese milk and cheese quality. Our findings were in line with (Barron et al., 2007), who reported that higher level of fatty acids and their derivatives were present in cheese produced from pasteurized milk than in raw milk cheese. In addition, (Vélez et al.,2010) reported a comparable fatty acid profile between cheese produced from raw or pasteurized milk. The higher level of fatty acids in heated milk Edam cheese might be related to the action of microbial enzymes and esterases as reported by Collins et al., (2003). On the other hand, Ortigosa et al. (2001) revealed that pasteurization reduced the level of fatty acids in cheese produced from pasteurized milk in comparison to raw milk cheese.

TABLE 6 . Free fatty acids of Edam cheese produced with different heat treatments .

Compound	Edam cheese produced from		
	Raw milk	Thermized milk (65 °C/15 sec.)	Pasteurized milk (72 °C/15 sec.)
Butyric acid	2.3	1.96	3.15
Caproic acid	2.1	2.04	2.55
Caprylic acid	1.6	1.29	1.8
Capric acid	3.37	3.48	4.08
Lauric acid	4.54	4.11	5.22
Myristic acid	16.58	15.66	16.94
Palmitic acid	43.33	40.74	40.2
Stearic acid	7.4	7.95	7.27
Elaidic acid	15.92	17.69	14.83
Linoleic acid	0.87	1.72	1.25
Coprostan-3β-ol	1.44	--	--
Icosapentaenoic acid	0.55	1.08	--
Linolenic acid	--	1.81	1.33
Arachidonic acid	--	0.78	1.36

Microbiological properties

As shown in Table 7, the total bacterial counts were higher in raw Edam cheese in comparison to other Edam cheese treatments. The highest number (7.45 log CFU/g) was recorded in raw Edam cheese, while the lowest (6.95 log CFU/g) was obtained in pasteurized Edam cheese. Total viable counts (TVC) decreased in all cheese treatments progressively during ripening period. The higher moisture content after brining favored the bacterial growth in cheese curd and increased the TVC, while it decreased till the end of ripening. There were significant differences ($p \leq 0.05$) between the experimental samples during ripening. This might be due the effect of heat treatment on the viability and counts of bacteria in heated cheese milk.

Yeasts and molds were not detected at the first stage of ripening in all Edam cheese samples. On the other hand, it appeared after two weeks of ripening in raw Edam cheese. It was not detected neither in Edam cheese produced from pasteurized milk nor in Edam cheese produced from thermized milk, which probably to the inhibition effect of such heat treatments on the growth of yeasts and molds. *E.coli* was not detected neither in Edam cheese produced from pasteurized, raw milk nor in Edam cheese produced from thermized milk.

TABLE 7. Microbiological properties of Edam cheese with different heat treatments

Property (log cfu/g)	Ripening period (days)	Edam cheese produced from		
		Raw milk	Thermized milk (65 °C/15 sec.)	Pasteurized milk (72 °C/15 sec.)
TVC	1	7.45±0.02a	7.07±0.03b	6.95±0.01c
	15	7.37±0.08a	6.90±0.02b	6.75±0.06c
	30	7.31±0.01a	6.72±00.02b	6.60±0.05c
	45	7.22±0.02a	6.62±0.04b	6.31±0.03c
Yeast & molds	1	ND	ND	ND
	15	1.79±0.10a	ND	ND
	30	2.10±0.07a	ND	ND
	45	2.35±0.05a	ND	ND
E.coli	1	ND	ND	ND
	15	ND	ND	ND
	30	ND	ND	ND
	45	ND	ND	ND
Lactococci	1	7.46±0.02b	7.51±0.01a	7.52±0.01a
	15	7.36±0.006b	7.41±0.01a	7.38±0.004b
	30	6.93±0.02c	6.98±0.02a	6.96±0.02b
	45	6.81±0.03b	6.92±0.04a	6.91±0.02a
Spores	1	2.14±0.13a	1.36±0.10b	ND
	15	1.94±0.03a	1.33±0.06b	ND
	30	1.75±0.07a	1.00±0.00b	ND
	45	1.63±0.12a	0.97±0.06b	ND
Staphylococcus	1	ND	ND	ND
	15	ND	ND	ND
	30	ND	ND	ND
	45	ND	ND	ND

Data expressed as means±standard deviation
ND= Not detected, TVC= Total viable count
Different letters in the same row indicate significant differences ($P \leq 0.05$)

The average *Lactococci* count in raw Edam cheese was determined at 7.46 log CFU/g and was significantly ($p \leq 0.05$) the lowest among all the experimental Edam cheese samples after brining of cheese Table 4. A significant reduction of *Lactococci* count was observed in all experimental cheese samples during ripening period. At the end of ripening period, the *Lactococci* counts were comparable between Edam cheese produced from thermized milk (6.92 log CFU/g) and Edam cheese produced from pasteurized milk (6.91 log CFU/g) at the 6th week of ripening. The high counts of *Lactococci* after brining of Edam cheese samples were largely determined by the higher moisture content in experimental cheeses. Similar results were reported by (Aljewicz et al., 2014). The higher levels of moisture contents in Edam cheese samples were a consequence of processing conditions. In addition, cheese loaves absorb more water while brining due to the absence of a natural cheese rind resulting in moisture increase in cheese network stimulating the microbial growth and activating the biochemical pathways during cheese ripening (Aljewicz et al., 2014). These results were in line with (Moser et al., 2018). Spores was detected in higher numbers in raw Edam cheese particularly at the earlier time of ripening and decreased during ripening. In addition, spores appeared in lower numbers in Edam cheese produced from thermized milk but was not detected in Edam cheese produced from pasteurized milk. This might be due to the severity of heat treatment and the prevention of spores from cheese milk. Staphylococcus was not detected in all Edam cheese samples.

TABLE 8. Sensory properties of Edam cheese with different heat treatments

Property	Ripening period (days)	Edam cheese produced from		
		Raw milk	Thermized milk (65 °C/15 sec.)	Pasteurized milk (72 °C/15 sec.)
Appearance	1	7.40±0.50a	7.40±0.70a	7.50±0.80a
	15	7.60±0.80a	7.80±0.90a	7.80±0.60a
	30	8.20±0.80a	8.30±0.80a	8.40±0.70a
	45	8.20±0.40a	8.40±0.70a	8.50±0.70a
Taste	1	6.90±1.10a	6.90±0.60a	6.90±0.99a
	15	7.40±0.96a	8.00±0.80a	8.10±0.70a
	30	7.90±0.60b	8.40±0.70ab	8.50±0.50a
	45	8.20±0.60b	8.60±0.50ab	8.80±0.40a
Texture	1	6.90±0.99a	7.10±0.30a	7.400.50a
	15	7.10±0.70a	7.40±0.80a	7.70±0.50a
	30	7.20±0.40c	8.00±0.00b	8.40±0.50a
	45	7.40±0.50c	8.10±0.30b	8.70±0.50a
Smell	1	6.10±0.60a	6.20±0.60a	6.10±0.60a
	15	6.80±0.60a	7.00±0.70a	7.10±0.60a
	30	7.30±0.50b	7.90±0.60a	8.00±0.70a
	45	7.60±0.50b	8.40±0.50a	8.60±0.50a
Overall acceptability	1	6.60±0.80a	7.10±0.90a	7.10±0.70a
	15	6.90±0.70b	7.70±0.70a	7.90±0.60a
	30	7.00±0.80b	8.30±0.50a	8.60±0.50a
	45	7.20±0.60b	8.50±0.50a	8.80±0.40a

Data expressed as means±standard deviation
Different letters in the same row indicate significant differences ($P \leq 0.05$)

Sensory evaluation

The sensory properties of Edam cheese produced from milk subjected to different heat treatments are shown in Table 5. There were no significant differences (P≤0.05) in appearance among all Edam cheese samples at the earlier time of ripening and during the whole ripening period. The taste, smell and texture of experimental Edam cheese were not significantly different (P≤0.05) among all Edam cheese samples till the 15th day of ripening. Edam cheese produced from pasteurized or thermized milk had the highest score of taste and smell from the 30th day of ripening till the end of ripening period without significant differences between both treatments. The lowest score of taste and smell was determined in raw Edam cheese. On the other hand, texture of Edam cheese produced from pasteurized milk was the superior over other treatments particularly from the 30th day of ripening till the end of ripening period. The higher score of taste, smell and texture of experimental Edam cheese might be related to the rate of proteolysis and the formation of free amino acids, free fatty acids, flavor compounds and the improvement of such sensorial properties. At the end of ripening period, Edam cheese produced from thermized milkor pasteurized milk were characterized by higher overall acceptability than raw Edam cheeses.

Conclusion

Different heat treatments were used in the production of Edam cheese.Heating cheese milk used in the production of Edam cheese significantly affected the physicochemical properties of experimental Edam cheese. Edam cheese produced from pasteurized milk was characterized by lower hardness values in comparison to Edam cheese produced from raw orthermized milk which probably due to the higher retention of water in cheese network affecting the structural properties of cheese curd. In addition, the application of heating to cheese milk had an impact on the formation of free fatty acids and the flavor compounds of Edam cheeses. Moreover, Edam cheeses produced from milk subjected to heating were characterized by higher and acceptable organoleptic properties due to the formation of free fatty acids and flavor compounds in cheese matrix which enhance the intensification of cheese flavor. Hence, heating milk to 72°C/15 sec could be used successfully in the manufacture of Edam cheese for producing acceptable Edam cheese with higher quality characteristics.

Compliance with ethical standards

The author declares no conflict of interest.

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