Slovak Society of Chemical Engineering
Institute of Chemical and Environmental Engineering
Slovak University of Technology in Bratislava

PROCEEDINGS

33rd International Conference of Slovak Society of Chemical Engineering

Hotel Hutník
Tatranské Matliare, Slovakia
May 22 – 26, 2006

Editors: J. Markoš and V. Štefuca

ISBN 80-227-2409-2

Effects of Ohmic Heating Technology in Chemical Properties of Foods

PEREIRA, R., PEREIRA, M., TEIXEIRA, J. A. and VICENTE, A. A.

*Centro de Engenharia Biológica Universidade do Minho, Campus de Gualtar,
4710 - 057 Braga, Portugal
E-mail: rpereira@deb.uminho.pt*

Abstract

In this work some food products where characterised chemically before and after ohmic and conventional heating treatments, comparing both processes. In each food type (cloudberry jam, goat milk) pH was measured and parameters such as total and volatile solids, ash, titratable acidity, ascorbic acid, total sugars, total fatty acids, total phenolic compounds and anthocyanins content were determined, depending on the food being analysed. In goat milk samples treated by ohmic technology, the titratable acidity 0.12 % (as lactic acid), pH value 6.59 and total fatty acids content in milk fat 86.5 g $100g^{-1}$ were comparable to those found in milk treated by conventional process. In cloudberry jam samples treated by ohmic technology the results of some of the main parameters tested, such as total sugar content 47.4 g $100g^{-1}$, ascorbic acid concentration 2.8 g $100g^{-1}$ and titratable acidity 6.01g $100g^{-1}$ (as citric acid) did not show significant differences for samples treated by conventional technology.

Keywords: ohmic heating, goat milk, total fatty acids, ascorbic acid.

Introduction

In recent years, the world's food industry has focused increasing attention on electrical techniques of food processing. Ohmic heating is one of these techniques that involve the passage of an alternating electrical current through a food product, allowing the generation of heat inside of it, in agreement with Joule's law. Indeed, the food behaves as a resistor in an electrical circuit [1]. Presently, most liquid foods are preserved commercially by ultra high temperature (UHT) or high temperature short time (HTST) processes. However the thermal processing of fruit purees and jams, for example, is traditionally difficult, essentially due to their rheological properties. The problem is aggravated when fruit particles are present in the slurry, as in the case of fruit purees to be incorporated in yoghurts. In fact, in order to process them fully to meet food safety requirements, an over-processing of the liquid phase is necessary. This is mainly due to the heat exchange mechanism used (conduction) and leads to important losses both in nutritional and organoleptic terms. The use of conventional heat exchangers is not possible and scraped surface devices are normally used, instead. The contact of the slurry with a hot surface is promoted and mixing is achieved by means of rotating blades. These are responsible for mechanical damage to the fruit particles affecting the final quality of the product and diminishing its acceptability to the consumer. The maintenance of such scraped surface heat exchangers is also more expensive than that of the most usual plate-and-frame or shell-and-tube options. In another example, it is widely accepted that raw milk cheeses are among the most appreciated for their unique flavour and taste, having an excellent market value, but it is also widely known that they present a safety problem to the consumer due to the use of raw milk. However, traditional pasteurisation implies the loss of nutritional and organoleptic qualities of the end product, be it milk itself or the cheese made from it, due to the high shear stresses imposed on milk during heat treatment in plate-and-frame heat exchangers (the ones normally employed to heat treat the milk to be used in cheese production). These high shear stress values destroy the fat globules and free their fatty acid content which

rapidly oxidises, producing off-odours and off-flavours. This effect is particularly true in the milk of small ruminants (sheep and goat). A safer product is obtained, then, but its properties are no longer compatible with those demanded for such high market value products. In general, the absence of a hot surface in ohmic heating reduces fouling problems and thermal damage to the product. Therefore, a high-quality product with minimal structural, nutritional, or organoleptic changes is expected which can be manufactured in a short operating time. The potential applications of this technique in food industry are very wide and include blanching, evaporation, dehydration, fermentation [2]; it can also be used as a continuous in-line heater for cooking and sterilization of viscous and liquid food products. According with Icier et al [3] ohmic heating is used in milk and fruit juice processing and is currently used for the processing of whole fruits in Japan and the United Kingdom, for production of syruped fruit-salad. Although the technology of ohmic heating appears to be promising and highly effective, there is little information concerning the effects of this technique on specific food products compared to conventional pasteurization [4], [5]. According to Sastry [6] the electrochemical aspects of ohmic processes are restricted to a few studies.
The aim of this work is to characterise chemically some food products before and after ohmic and conventional heating treatments, comparing the effects of both processes in terms of food's chemical properties and subsequent quality.

Experimental

Materials

In the present study two different food products were analyzed, goat milk and cloudberry jam, obtained from jam and goat cheese producers. For this purpose, samples of the food products under study were requested in the following way: unprocessed samples collected in the moment just before entering the process; processed samples treated conventionally and ohmically, from the same lot of production, collected at five different times (if a continuous process) or five volumes randomly chosen (if a batch process). All the samples (goat milk and cloudberry jam) were kept at -18 ºC until all experiments were carried out.

Methods

Cloudberry jam preparation and extraction: Frozen samples of cloudberry jam (100 g in triplicate) were homogenized and smashed using a Moulinex Commercial Turbo Blender. The pits of jam were drained off before centrifuging (5 minutes at 10000 rpm) to gain juice. The homogenates were kept under refrigeration (4 ºC) until use.

pH and total acidity: Measure of pH and total acidity were performed according to the Official Methods of Analysis of AOAC [7] using a pH-meter. The total acidity was measured by titration with 0.1 mol L^{-1} NaOH solution.

Total solids and ash: A well mixed sample of food product was evaporated in a weighted dish with washed sea sand (Panreac ref: 211160) and dried to a constant weigh at 103-105 ºC. Solids remaining after the analysis for total solids were ignited at 550 ± 50 °C to a constant weight. The volatile portion of the solids was determined by the weight loss as a result of the ignition [7].

Analysis of Ascorbic Acid: The homogenate of cloudberry jam (6 g) was added to 20 mL of 4.5 % metaphosphoric acid and the mixture was centrifuged at 4000 rpm for 15 min at 20 ºC. The supernatant was filtered through a 0.45 µm cellulose prior to injection. Analysis was performed by High Performance Liquid Chromatography (HPLC), using a Jasco 880-PU intelligent HPLC pump equipped with a Jasco 870-UV intelligent UV-VIS detector and a Jasco AS-2057 Plus intelligent auto sampler. The mobile phase was 0.005 mol L^{-1} sulphuric acid in ultrapure water. The flow rate was 0.7 mL min^{-1} and the detection wavelength was 245 nm. All samples were run in triplicate and the linearity was determined from 0.02 to 0.08 μg μL^{-1} with a 10 μL injection volume. The ascorbic acid peak was identified on the sample chromatogram by retention time according to chromatograms of the standard solutions. The peak areas were integrated, and checked for interference or substances other than ascorbic acid eluting at the same retention time.

Analysis of sugars: The homogenate of cloudberry jam (6 g) was added to 20 mL of ultrapure water and were centrifuged at 1000 rpm for 5 min at 20 ºC. Aliquots of supernatant were filtered through a 0.2 μm (CA-PC 30 mm) cellulose acetate membrane prior to injection. The soluble sugars (sucrose, glucose and fructose) were analyzed by HPLC using a Jasco 880-PU intelligent HPLC pump equipped with a Jasco 830-RI intelligent RI detector and a Jasco AS-2057 Plus intelligent auto sampler. Sucrose, glucose and fructose (sgf) peaks were identified and quantified by the retention time and peak areas of a standard solution. All samples were run in triplicate.

Total phenolics: Total soluble phenolics were determined with Folin–Ciocalteu reagent according to the method of Slinkard and Singleton [8] using gallic acid as a standard. Results were expressed as milligrams of gallic acid equivalents (GCE) per hundred grams of product.

Total anthocyanins: Total anthocyanin content was estimated using the pH differential assay of Giusti and Wrolstad [9] and Fuleki [10]. Absorbance was at 520 and 700nm in buffers at pH = 1.0 and pH = 4.5, using the following equation:

$$A = (A_{520} - A_{700})_{\text{pH}=1.0} - (A_{520} - A_{700})_{\text{pH}=4.5} \quad (1)$$

with a molar extinction coefficient of cyanidin-3-glucoside (C3G) of 29 600. Results were expressed as milligrams of cyanidin-3-glucoside per hundred grams of product.

Total Fatty acids in milk: Analysis of total fatty acids composition was conducted by gas chromatography (GC). The response obtained with the samples was compared with that of standard fatty acid methyl esters (FAMEs). Analysis of fatty acids in goat milk samples was conducted in two major steps: lipid extraction and methyl esters preparation. Extraction of lipids in solution was done according with the method of Bligh and Dyer [11]. FAMEs were prepared using sodium methylate (0.5 mol L^{-1}) and sulphuric acid in methanol (5 %) according with Canada [12]. Analyses were performed on a CP 9001 gas chromatograph (Chrompack) equipped with a split injection port, flame ionization detector and phase TR-WAX capillary column (30 m – 0.32 mm – 0.25 μm, Teknokroma) equivalent to a CP-SIL 52CB. The temperature of both the injector and detector were at 250 °C. The initial oven temperature was set at 150 °C for 2 min; it was then programmed to increase at a rate of 10 °C min until it reached 220 °C, and was then maintained at this temperature for 20 min. The samples (1 μL) were injected manually using the hot injection technique. For calibration were prepared methyl esters from analytical standards from free fatty acids stock solutions (C4:0 - C18:1). Individual fatty acids were quantified by the internal standard technique, using methylated tridecanoic acid (C13:0) as an internal standard.

Results and Discussion

Goat milk: The results of chemical analysis (pH, total acidity, total solids, ash and fatty acids) performed in processed, ohmic and unprocessed goat milk are presented in Table 1.

Table 1. Results of chemical analysis performed in unprocessed, ohmically processed and conventionally processed goat milk.

Tests performed	Conventional	Ohmic	Unprocessed
pH	6.59 ± 0.04	6.59 ± 0.05	6.61 ± 0.07
Total Acidity (% lactic acid)	0.134 ± 0.003	0.124 ± 0.004	0.132 ± 0.003
Total Solids (%)	14.7 ± 0.30	14.9±0.1	14.7±0.1
Ash (%)	1.3 ± 0.1	1.1 ± 0.1	1.0 ± 0.1
TFA (g 100 g^{-1} $_{\text{of milk fat}}$)	88.2 ± 4.7	86.5 ± 7.0	89.5 ± 10.6

In unprocessed samples, the pH (6.61 ± 0.07), percentage of total acidity, as lactic acid (0.134 ± 0.004) and total solids (14.7 % ± 0.1 %) were within the normal range for fresh goat milk (6.61 ± 0.07) [13], [14], however content of ash was slightly higher (1.0 % ± 0.1 %). This difference can be explained based on the fact that ash, which is one of the major soluble components regulating the osmotic pressure of milk, can be subjected to modifications during the lactation period [15]. The results of parameters analyzed in samples processed by ohmic heating such as, pH (6.59 ± 0.05), percentage of lactic acid (0.124 % ± 0.004 %), total solids (14.9 % ± 0.1 %) and ash (1.1 % ± 0.1 %) showed a good similarity with those obtained for goat milk samples processed by conventional heating. Both samples (ohmic and conventional) exhibited results in the same range of variation. The mean values of FAMEs concentration, obtained by gas chromatography (see Figure 1 for an example of a chromatogram) and their respective ranges of variation in samples of milk unprocessed and processed (both conventionally and ohmically) are given in Table 2.

In samples of unprocessed goat milk the most abundant FAME was palmitic (27.89 ± 0.89 g 100 g^{-1}), followed by oleic (26.73 ± 4.55 g 100 g^{-1}), stearic (13.35 ± 4.04 g 100 g^{-1}), myristic (7.41 ± 0.89 g 100 g^{-1}) and capric (5.56 ± 1.07 g 100 g^{-1}). The weight percentage of these fatty acids accounted for 87.0% of the total FAMEs in unprocessed milk fat. Similarly the samples of goat milk treated by ohmic heating showed that palmitic (25.16 ± 1.92 g 100 g-1), oleic (24.38 ± 2.37 g 100 g^{-1}) , stearic (12.08 ± 1.09 g 100 g-1), myristic (6.87 ± 0.65 g 100 g^{-1}) and capric (5.71 ± 0.72 g 100 g^{-1}) were the major FAMEs in milk fat, representing a weight percentage of 85.8 %. The FAMEs concentration obtained for goat milk treated by ohmic heating are quite comparable to those found in milk treated conventionally (Figure 2), where palmitic, oleic, stearic, myristic and capric also represent 85.4 % of the total FAMEs. The FAMEs profiles in this study are in accordance with the findings of other authors [16], [17]. However there is a relationship between the fat content and the fatty acid concentration, the higher the fat content of goat milk the greater the fatty acid concentration.

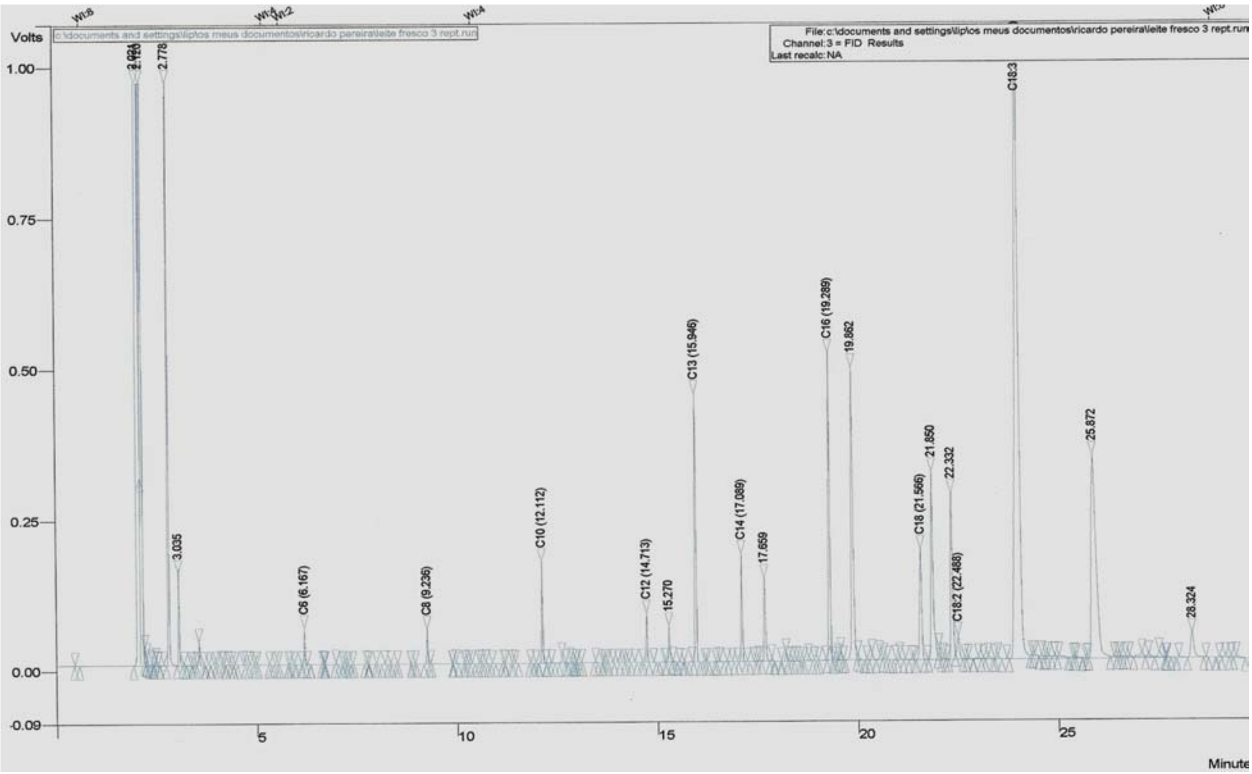

Figure 1. An example of a GC chromatogram of FAMEs in unprocessed goat milk fat.

Table 2. Fatty acids concentration (g 100 $g^{-1}{}_{\text{of milk fat}}$) in unprocessed, ohmically processed and conventionally processed goat milk fat.

Fatty Acid	Conventional	Ohmic	Unprocessed
Butyric (C4:0)	2.23 ± 0.52	2.26 ± 0.66	1.84 ± 0.33
Caproic (C6:0)	1.90 ± 0.15	1.81 ± 0.22	1.63 ± 0.32
Caprylic (C8:0)	1.90 ± 0.10	1.73 ± 0.19	1.62 ± 0.34
Capric (C10:0)	6.38 ± 0.30	5.71 ± 0.72	5.56 ± 1.07
Lauric (C12:0)	3.06 ± 0.12	2.80 ± 0.33	2.88 ± 0.38
Myristic (C14:0)	7.15 ± 0.19	6.87 ± 0.65	7.41 ± 0.89
Palmitic (C16:0)	24.53 ± 0.65	25.16 ± 1.92	27.89 ± 0.89
Stearic (C18:0)	12.15 ± 1.08	12.08 ± 1.09	13.35 ± 4.04
Oleic (C18:1)	25.05 ± 1.96	24.38 ± 2.37	26.73 ± 4.55
Linoleic (C18:2)	3.81 ± 5.11	3.70 ± 0.50	4.15 ± 0.64

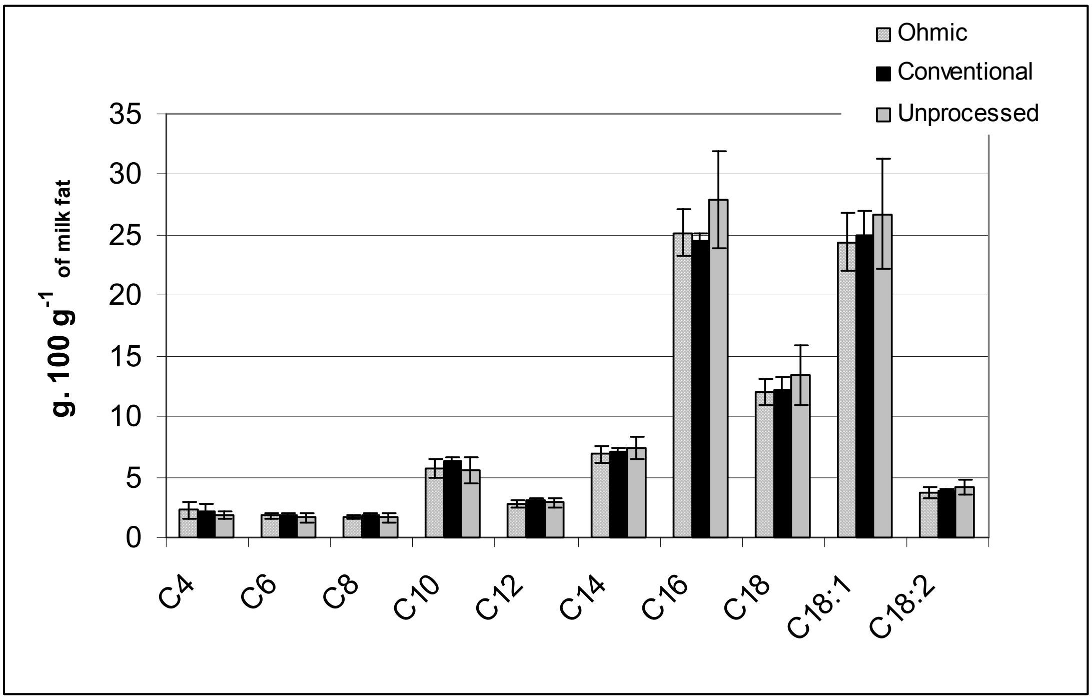

Figure 2. FAMEs composition in unprocessed, ohmically processed and conventionally processed goat milk fat.

On the other hand, qualitative milk production of dairy goats depends upon nutritional supply [18]. A direct comparison of these results with those from the literature is quite difficult because authors do not always state the breed, lactation period and number of samples analysed. Furthermore, the samples were differently treated and different extraction and transesterification methods were used. For these reasons differences in concentrations of fatty acids calculated in this study could be noticed when compared with previous reports.

Cloudberry jam: In samples processed by ohmic heating the pH (3.65 ± 0.10), total solids (40,.0 % ± 0.6 %), ash (0.23 % ± 0.02 %), ascorbic acid (2.76 ± 0.08 mg.100 $g^{-1}_{of\ product}$) phenolic compounds (150.9 ± 1.8 mg_{GCE} 100 $g^{-1}_{of\ product}$) and anthocyanins (0.36 ± 0.01 mg_{C3G} 100 $g^{-1}_{of\ product}$) were similar to those obtained for conventionally processed jam (Table 3). The pH of cloudberry jam in all samples was within other similar products ranging from 3.10 to 3.70 [19].

Table 3. Results of chemical analysis performed in unprocessed, ohmically processed and conventionally processed cloudberry jam.

Tests performed	Conventional	Ohmic	Unprocessed
pH	3.83 ± 0.03	3.65 ± 0.10	3.37 ± 0.06
Total Acidity (g $_{Citric\ acid}$ 100 $g^{-1}_{of\ product}$)	6.18 ± 0.08	6.01 ± 0.01	6.34 ± 0.08
Total Solids (%)	39.5 ± 0.3	40.0 ± 0.6	39.5 ± 0.6
Ash (%)	0.23 ± 0.01	0.23 ± 0.02	0.21 ± 0.01
Anthocyanins (mg_{C3G} 100 $g^{-1}_{of\ product}$)	0.36 ± 0.02	0.36 ± 0.01	0.70 ± 0.02
Total Phenolics (mg_{GAE} 100 $g^{-1}_{of\ product}$)	149.4 ± 7.4	150.9 ± 1.8	144.5 ± 3.6
Ascorbic Acid (mg 100 $g^{-1}_{of\ product}$)	2.88 ± 0.08	2.76 ± 0.08	3.08 ± 0.10
Total Sugars (g_{sgf} 100 $g^{-1}_{of\ product}$)	46.48 ± 0.95	47.37 ± 1.11	34 ± 2.39

According to Thiem [20], the main phenolic compound in cloudberries is ellagic acid. Cloudberries have a high ellagic acid content (160 mg per 100 g seedless dry weight) [21], which can be comparable with results obtained for total phenolics in all samples of cloudberry jam. However according to Kähkönen [22] values obtained for total phenolics and anthocyanins were substantially lower. That author explains this by the fact that the specificity or the sensitivity of method used was not enough to allow a good recovery for all phenolic subclasses. On the other hand concentration of these compounds in samples could have been reduced during the preheating stage at 60 ºC that unprocessed samples undergo before pumping and inlet to ohmic and conventional heat treatment. Heat treatments cause a significant reduction of the concentration of thermolabile compounds. For this reason unprocessed jam presented higher concentration of anthocyanins, citric and ascorbic acid, than jam processed by ohmic and conventional heating. The jam's processed by ohmic and conventional heating presented a concentration of total sugars of 47.37 ± 1.11 g_{sgf} 100 $g^{-1}{}_{of\ product}$ and 46.48 ± 0.95 g_{sgf} 100 $g^{-1}{}_{of\ product}$, respectively, slightly higher than those found in unprocessed samples (Table 4).

Table 4. Results of the sugars concentration (g 100 $g^{-1}{}_{of\ product}$) in unprocessed, ohmically processed and conventionally processed cloudberry jam.

Sugars	Conventional	Ohmic	Unprocessed
Glucose	10.30 ± 0.23	10.81 ± 0.27	3.76 ± 0.28
Fructose	10.23 ± 0.23	10.75 ± 0.25	3.59 ± 0.25
Sucrose	25.95 ± 0.49	25.81 ± 0.59	27.55 ± 1.86

In both samples (ohmic and conventional) sucrose was the main sugar, representing about 55 % of weight percentage of total sugars. However the jam unprocessed presented a higher content of sucrose (78.9 %). This can be justified by the fact that jam producers often add sucrose, which acts as a dehydrating agent, in order to decrease water content [23]. Concentration of glucose and fructose was equivalent in both processed samples (ohmic and conventional) and higher than that of unprocessed jam, due to inversion of sucrose during processing. Factors such as the duration of exposure to high temperatures, the degree of acidity or the pH of the mixture must be considered in order to control the amount of inverted sugar produced by boiling [24].

Conclusion

In general and concerning the parameters studied, the results of chemical analysis indicate that ohmic heating technology provides products with chemical properties similar to those of the products obtained by conventional treatment. This is important because it allows the producers to replace the methods without major changes in their final products.

References

[1] HALLEUX, D. PIETTE, G. BUTEAU, M.L. AND DOSTIE, M.. Ohmic cooking of processed meats: Energy evaluation and food safety considerations **-** *Canadian Biosystems Engineering/Le génie des biosystèmes au Canada 47: 3.41 - 3.47.* 2005.

[2] CASTRO , J.A. TEIXEIRA , S. SALENGKE , S.K. SASTRY , A.A. VICENTE. Ohmic heating of strawberry products: electrical conductivity measurements and ascorbic acid degradation kinetics. *Innovative Food Science and Emerging Technologies 527–36.* 2004.

[3] ICIER, F., ILICAL, C..Temperature dependent electrical conductivities of fruit purees during ohmic heating. *Food Research International 38 (2005) 1135–1142.*

[4] LEIZERSON S, SHIMONI E,. Effect of Ultrahigh-Temperature Continuous Ohmic Heating Treatment on Fresh Orange Juice. *J. Agric. Food Chem. 2005, 53, 3519-3524 3519.*

[5] ICIER, F., ILICAL, C..The effects of concentration on electrical conductivity of orange juice concentrates during ohmic heating. *Eur Food Res Technol (2005) 220:406–414.*

[6] SASTRY, S. ASSIRY, A. SAMARANAYAKE, C. - Degradation kinetics of ascorbic acid during ohmic heating with stainless steel electrodes. *Department of Food, Agricultural and Biological Engineering. 2002.*

[7] OFFICIAL METHODS OF ANALYSIS OF AOAC (ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS) *International Official Methods; 16 Th Edition , Volume II – Food composition; additives; natural contaminants. Supplement March – 1996.*

[8] SINGLETON V.L , SLINKARD K., Total phenol analysis, automation and comparison, with manual methods. *AM. J. Enol. Vitic, 1997.*

[9] GIUSTI, M. M., RODRIGUEZ-SAONA, WROLSTAD, R. E.. Molar Absorptivity and Color Characteristics of Acylated and Non-Acylated Pelargonidin-Based Anthocyanins, *J. Agric. and Food Chemistry*, vol. 47, No. 11, pp 4631-4637 – 1999.

[10] FULEKI, T., FRANCIS, F.J.. Quantitative Methods for Anthocyanins. 2. Determination of Total Anthocyanin and Degradation Index for Cranberry Juice, *J. Food Science, Vol. 33, pp 78-83 – 1968.*

[11] BLIGH E.G., DYER W.J. A rapid method f total lipid extraction and purification, *Can. J. Biochem Physiol. - 1959.*

[12] CANADA, J. S. – Caracterización Sensorial y Fisico – Quimica del Queijo Serpa. *PhD Dissertation*, *2001*, *Universidad Extramdura, Facultad Veterinaria Caceres*

[13] TODARO, M., SCATASSA, M. L., Giaccone, P.. Multivariate factor analysis of Girgentana goat milk. *Ital. J.Anim. Scl. Vol. 4, 403-410, 2005.*

[14] KANWAL, R. AHMED, T. MIRZA, B.. Comparative Analysis of Quality of Milk Collected from Buffalo, Cow, Goat and Sheep of Rawalpindi/Islamabad Region in Pakistan. *Asian Journal of Plant Sciences 3 (3): 300-305, 2004.*

[15] KESKİN, M., AVŞAR, Y. K., BiÇER, Osman. A Comparative Study on the Milk Yield and Milk Composition of Two Different Goat Genotypes under the Climate of the Eastern Mediterranean. Turk *J Vet Anim Sci 28 (2004) 531-536.*

[16] KONDYLI, E., KATSIARI, M.C. Fatty acid composition of raw caprine milk of a native Greek breed during lactation. *Int. J. Dairy Technol. 1, 57–60, 2002.*

[17] POSATI, L.P., ORR, M.L.. Composition of Foods, Dairy and Egg Products. *Agriculture Handbook No. 8-1.USDA-ARS. Consumer and Food Economics Institute Publisher,Washington, DC,pp. 77–109, 1976.*

[18] GREPPI, G. F., CICERI, A., PASQUINI, M., FALASCH, U., ENNE, G.: Milk yield in dairy goats and blood metabolites.In: *Proceedings of IDF-Seminar on Production and Utilization of Ewe's and Goat's Milk, 19-21; October, Greece. 47 p. 1995.*

[19] SUUTARINEN, M. Effects of prefreezing treatments on the structure of strawberries and jams.VTT Biotechnology *PhD Dissertation, 2002, Helsinki University of Technology, Espoo, Finland*

[20] THIEM, B. - *Rubus chamaemorus* L. – a boreal plant rich in biologically active metabolites: a review. *Biol. Lett. 2003, 40(1): 3.13.*

[21] HÄKKINEN S. H., HEINONEN M., KÄRENLAMPI S., MYKKÄNEN H., RUUSKANEN J., TÖRRÖNEN R. 1999. Screening of selected flavonoids and phenolic acids in 19 berries. *Food. Res. Int. 32:345.353.*

[22] KÄHKÖNEN, M. P., HOPIA, A. L. , HEINONEN, M. Berry Phenolics and Their Antioxidant Activity Department of Applied Chemistry and Microbiology. *J. Agric. Food Chem. 2001, 49, 4076̃408.*

[23] PONTING, J.D., WATTERS, G.G., FORREY, R.R., JACKSON, R. & STANLEY, W.L. 1966. Osmotic dehydration of fruits. *Food Tech., Vol. 20, pp. 1365.1368.*

[24] MOLYNEUX, F. Manufacture of jams, sauces and pickles. *Process Biochem., Vol. 6, pp. 17.18, 1971.*