Journal of Energy and Safety Technology

JEST

RESEARCH ARTICLE Open Access

Determination of the Chemical Content in Goat's Milk Based on Dielectric Properties for the Purpose of Standardisation Process in Yogurt Production

Nur H. Hanafi[1,2], Mimi H. Hassim[1,2*], Ahmad K. F. Ismail[1,2] Mohd J. Kamaruddin[1,2], Nik A. Nik A. Mahmood[3], Yanti M. Mohd Jusoh[3], Muhd Nazrul Hisham Zainal Alam[3], Sani Amril Samsudin[3], Anwar Johari[1,2]

1 Department of Chemical Engineering, School of Chemical and Energy Engineering, Faculty of Engineering, Universiti Teknologi Malaysia, 81310 Johor Bahru, Johor, Malaysia

2 Centre of Hydrogen Energy (CHE), Institute of Future Energy, Universiti Teknologi Malaysia, 81310 Johor Bahru, Johor, Malaysia

3 Department of Bioprocess and Polymer Engineering, School of Chemical and Energy Engineering, Faculty of Engineering, Universiti Teknologi Malaysia, 81310 Johor Bahru, Johor, Malaysia

**Corresponding Author: mimi@cheme.utm.my*

Article History

Received: January 13, 2020 Received in revised form: December 22, 2021 Accepted: January 03, 2022 Published Online: June 15, 2022

Abstract

A study was performed to obtain the chemical content of goat's milk (fat, protein and carbohydrate) using dielectric properties (dielectric constant and dielectric loss factor) for the purpose in developing standard which will be used for yogurt production. The purpose of this study is to standardized the milk to produced the best quality of yogurt. The dielectric properties of goat's milk with known chemical content were of measured from 201 to 4500 MHz at room temperature using a network analyzer and an open-ended coaxial line probe which then used in creating empirical model. Three samples of commercialize goat's milk which available in local market were studied for the purpose in creating this empirical formula. Chemical content of four raw goat's milks samples were then determined using the data of dielectric properties and empirical formula which was created before. The result show that the raw goat's milk consist of 4.99 to 8.08 wt% of fat content, 4.82 to 6.31 wt% of protein content and 7.12 to 9.15 wt% of carbohydrate content. Twenty standard chemical composition of commercialize plain goat yogurt were used in study and being used to compared with the chemical content of the raw goat's milk sample. As the raw goat's milk chemical composition was much higher comparing to the twenty commercialize plain goat yogurt, some action need to be done in decreasing the value of fat, protein and carbohydrate of the raw goat's milk.

Keyword: Goat milk, dielectric, Yogurt

1.0 INTRODUCTION

Yogurts are one of the cultured dairy product that widely consumed worldwide because it can easily be made and contain a lot of health benefit. Standardization is the initial step and one of the important stages of yogurt production as it adjusts the fat content and other solid content by the method of mixing milk with skim milk and cream to the desired level by manufacture [1]. Each goat will produce different value of chemical composition in their milk due to a lot of factors such as food intake, breeding season and sleep patent. Thus, it is important that all of this milk need to be standardized first as this will affect the quality of the yogurt. As changing chemical composition will affect culture activity, yogurt consistency and viscosity and affected pH rate changes in any process [3,4]. Ozer and Robinson (1999) study shows that chemical composition such as fat content and protein content also influenced the growth and activity of the culture medium [2].

Dielectric analysis is one of many analyses that can be used for detecting chemical compositions inside foods. Almost all foods contain electrical energy inside them. Dielectrics are a class of material which is poor conductors of electric and many materials such as living organisms and agriculture products conduct electric in some degrees which can classify as dielectrics [5]. As water is a strongly polar solvent and it is the major chemical constituent of most food

product, electric can flow through it. Besides that, nutrient content inside food which consists of ions such as calcium and potassium can also be a good electrical conductor. As yogurt and milk is in the form of water and have a lot of types of nutrient contain, dielectric analysis can easily be done by using the analyzer. Benefit of using this method compared to the other methods are the measurement is non-destructive, quick, simple to conduct and no sample preparation needs to be done. As chemical composition can easily be determine on the milk, standardization process can also easily to proceed. Studies by Xinhua Zhu *et al.* (2014) and Xinhua Zhu *et al.* (2015) indicated that dielectric can be used in determined the chemical composition of milk. They first study using protein in 2014 and then using fat in 2015 [5,6]. The study is to understand the effect protein and fat content on dielectric properties of raw milk and provide information for developing protein/fat content detector being suitable for real time quality monitoring.

2.0 METHODOLOGY

2.1 Sampling

Three brands of commercially available goat's milks from the local market were chosen for this study. The three goat's milks were from the company named Nubian, Rassuria and Misz. Raw goat's milk was obtained from a healthy *Saanen* goat at a farm located in Ulu Tiram, Johor, Malaysia. This raw goat's milk was collected once a week for one month, thus resulting in a total of four samples altogether was collected. The fresh milk raw milk was transport from the local farm to laboratory at room temperature in 30 min and stored in a refrigerator at 4 °C before the experiment. The milk samples were used within 36 hours after milking process to avoid contamination which will affect the result.

2.2 Sample Preparation

100 ml of commercialized and raw goat's milks were poured into a beaker and the mass of the milks were measured using electronic balance with a precision of 0.0001 g. By comparing with nutritional value fact that was provided by the company, the percentage of fat, protein and carbohydrate of the commercialized milk for each sample of the goat's milks were calculated. All of these 100 ml goat's milk samples were then undergoes dielectric analysis. Another 100 ml of the commercialized milks were diluted with 900 ml of deionised distilled water inside a beaker and the mass were measured using electronic balance. The percentage value of fat, protein and carbohydrate were then being calculated. All of these 1000 ml diluted goat's milk samples were then undergoes dielectric analysis.

2.3 Dielectric Property Measurement

For measuring dielectric, all instruments consist of vector network analyzer, open ended coaxial probe, coaxial cable, dielectric probe kit software and a computer were set up based on the setup shown in Figure 1. The frequency was set around 201-4500 MHz and measurements were done at 201 discrete. The equipment was first calibrated before use to avoid any reading error. The network analyzer was calibrated with the probe connected through its special cable to the Test Set with measurements on air, a short circuit, and a triple-distilled-water sample at 25 °C.

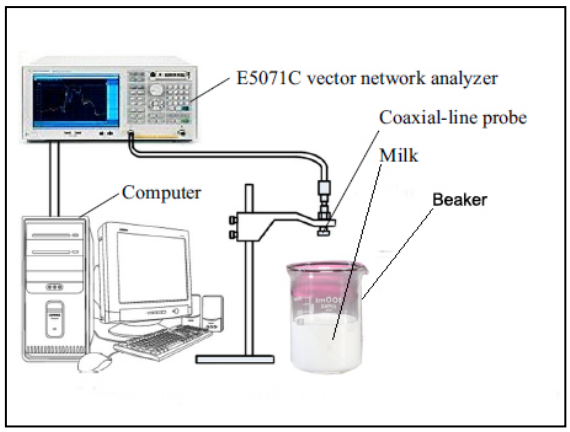

Figure 1: Schematic diagram of dielectric property measurement system setup.

2.4 Empirical Modeling

The regression mathematical models, which describe the relationship between permittivity (ε' and ε″) and chemical content (fat, protein and carbohydrate) at selected frequency, were established using Microsoft Excel 2010. This model was constructed based on the data obtained from the commercialized goat's milk only. This mathematical model was then

being used to determine the chemical content of raw goat's milk.

2.5 Standardization of Milk

Twenty standards of chemical content of goat milk yogurt were searched and being compared with the raw milk chemical composition. Suitable standard of the chemical content for the raw milk for the purpose yogurt production was then suggested.

3.0 RESULT AND DISCUSSION

3.1 Dielectric On Commercialize Milk

The percentage value of fat, protein and carbohydrate for 100 ml commercialized goat's milk and 1000 ml diluted commercialized goat's milk samples from three different companies - Nubian, Rassuria and Misz were calculated and the values obtained were summarized in Tables 1 and 2.

Table 1: Chemical composition in 100 ml of commercialized goat's milks

No	Company name	Mass (g)	Chemical composition (wt %)		
			Fat	Protein	Carbohydrate
1	Nubian	100.6030	3.78	2.98	6.66
2	Rassuria	98.0090	4.59	3.98	3.78
3	Misz	104.5321	9.62	10.29	11.08

Table 2: Chemical composition in 1000 ml of diluted commercialized goat milk's

No	Company name	Mass (g)	Chemical composition (wt%)		
			Fat	Protein	Carbohydrate
1	Nubian	979.6625	0.39	0.31	0.68
2	Rassuria	975.7768	0.46	0.40	0.38
3	Misz	957.7881	1.05	1.13	1.21

All these three samples of commercialized goat milk undergoes dielectric analysis using frequency of 201-4500 MHz at room temperature to obtain the dielectric constant (ε′) and the dielectric loss factor (ε″). Figures 2, 3 and 4 show the effect of dielectric constant (ε′) of goat's milk samples at 915 MHz at 25 °C if the fat, protein and carbohydrate content changes. All figures show the same pattern - the dielectric constant increases if the chemical content decreases.

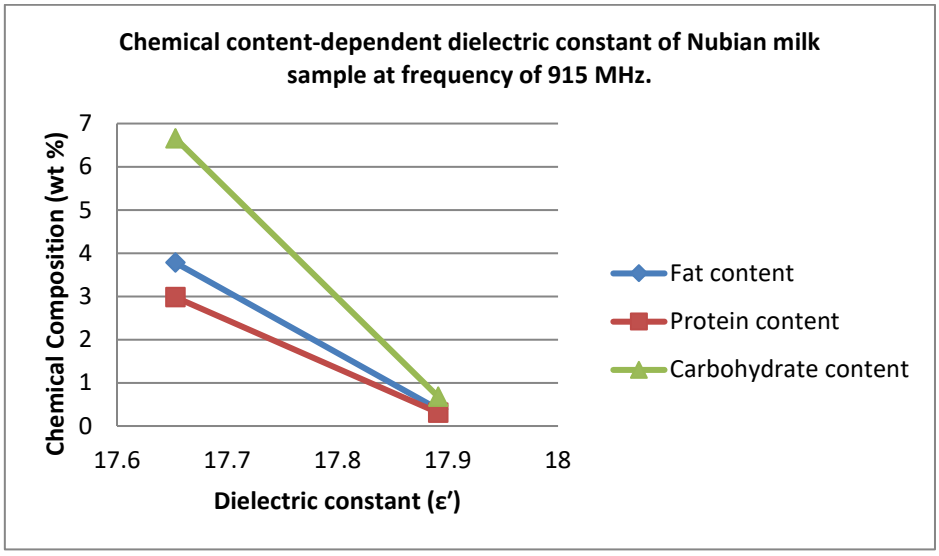

Figure 2: Chemical content-dependent dielectric constant of Nubian milk sample at frequency of 915 MHz.

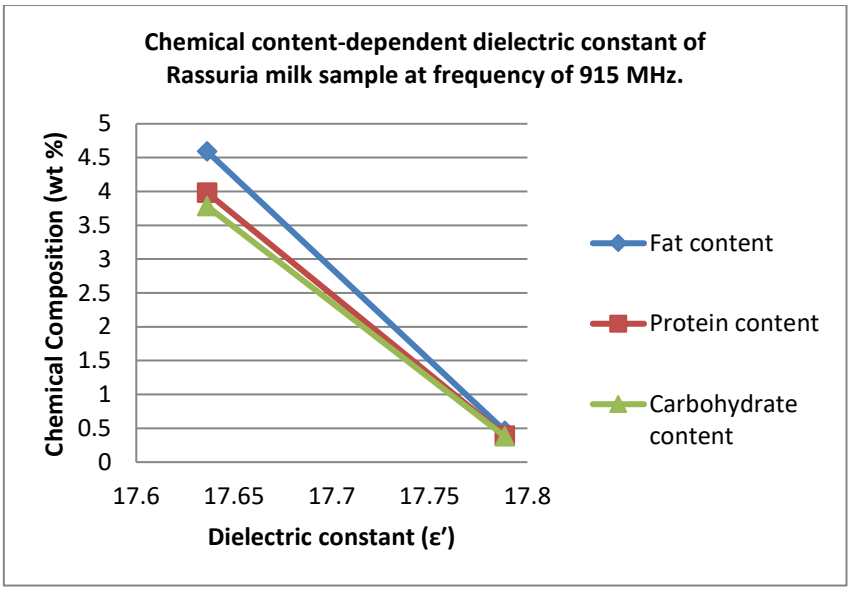

Figure 3: Chemical content-dependent dielectric constant of Rassuria milk sample at frequency of 915 MHz.

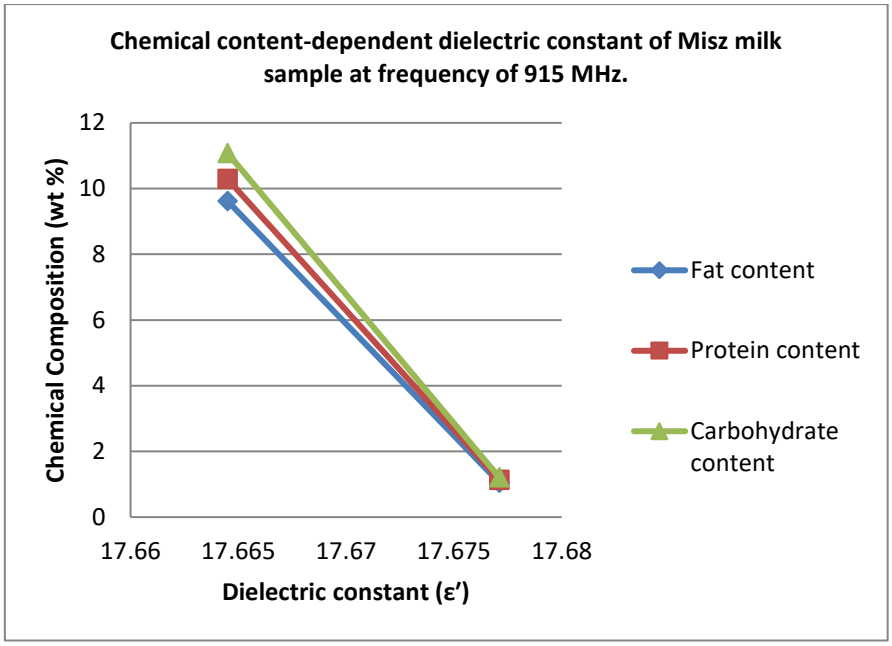

Figure 4: Chemical content-dependent dielectric constant of Misz milk sample at frequency of 915 MHz.

At frequency of 915 MHz with temperature 25 °C, the linear relationship between dielectric constant (ε′) and chemical content could be described by the following equation:

$$\varepsilon' = aP + b \quad (1)$$

where ε′ is the dielectric constant of goat milk obtained at different composition of chemical content, P is the chemical content in percentage (%) and a and b are the regression constants. The regression constants which will be used for Eq. (1) are listed in Table 3.

Table 3: The regression constants of Eq. (1) at selected frequency with temperature of 25 °C.

Type of milk	Frequency (MHz)	Fat		Protein		Carbohydrate	
		a	b	a	b	a	b
Nubian	915	-0.0701	17.6254	-0.0893	17.9189	-0.0399	17.9183
Rassuria		-0.0369	17.8055	-0.0423	17.8046	-0.0448	17.8055
Misz		-0.0015	17.6786	-0.0014	17.6787	-0.0013	17.6786

3.2 Dielectric on Raw Goat's Milk

The four samples of raw goat's milk which were obtained weekly undergo dielectric analysis using frequency of 201-4500 MHz at room temperature and the results of dielectric constant (ε′) at 915MHz with temperature of 25 °C were shown in Table 4.

Table 4: Dielectric constant (ε′) of 100 ml raw goat's milk samples at 915MHz with temperature of 25 °C.

Sample of goat's milk	Volume (ml)	Mass (g)	Frequency (MHz)	Temperature (°C)	Dielectric constant (ε′)
Week 1		102.2394			17.5346
Week 2	100	102.6391	915	25	17.4791
Week 3		102.4735			17.5648
Week 4		102.3180			17.5037

Chemical compositions of the raw goat's milk were calculated using Eq. (1) with the regression constant obtained from the Nubian, Rassuria and Misz milk samples. The fat, protein and carbohydrate contents calculated were shown in Tables 5, 6 and 7. Sample obtained in different week contains different composition of fat, protein and carbohydrate due to the mixture of several milk goats and the condition of the goats which produce different chemical composition. However, the differences are not very significant. The value of fat content calculated was around the range of 4.99 to 8.08%. The value of protein content calculated was around the range of 4.82 to 6.31%. The value of carbohydrate content calculated was around the range of 7.12 to 9.15%. However, Misz empirical formula cannot be used in protein and carbohydrate content calculation as it produces large different of chemical composition compared to the other two formulas.

Table 5: Calculated fat content of raw goat's milk by using Eq. (1).

Sample of goat's milk	Fat content (%)			
	Nubian	Rassuria	Misz	Mean±SE
Week 1	1.29	7.34	9.60	6.08±2.85
Week 2	2.09	8.85	13.30	8.08±5.65
Week 3	0.86	6.52	7.59	4.99±3.61
Week 4	1.74	8.18	11.66	7.19±5.04

Table 6: Calculated protein content of raw goat's milk by using Eq. (1).

Sample of goat's milk	Protein content (%)			
	Nubian	Rassuria	Misz	Mean±SE
Week 1	4.30	6.38	-	5.34±1.47
Week 2	4.92	7.70	-	6.31±1.97
Week 3	3.97	5.67	-	4.82±1.20
Week 4	4.65	7.11	-	5.88±1.74

Table 7: Calculated carbohydrate content of raw goat's milk by using Eq. (1).

Sample of goat's milk	Carbohydrate content (%)			
	Nubian	Rassuria	Misz	Mean±SE
Week 1	9.61	6.05	-	7.83±2.52
Week 2	11.01	7.29	-	9.15±2.63
Week 3	8.86	5.37	-	7.12±2.47
Week 4	10.39	6.74	-	8.57±2.58

3.3 Standardization Of Chemical Composition In Goat's Milk

Table 8 shows some chemical composition standards of the commercialized plain yogurt which is used by different companies. As they were already well-known company for yogurt production from goat milk, the standards that they use seem to be the best for consumption. As for fat content, the milk samples from almost all companies contain the composition between 4.0 to 5.9% for 100 g serving size. No further adjustment is required for the fat composition in the raw goat's milk since the content is almost the same as the standard fat composition of the commercialized plain yogurt. However, for some samples of milk with the fat content value as high as 8.0 %, the fat content needs to be reduced. This can be done by mixing skimmed milk with the sample to reduce its fat content.

The protein compositions for raw goat milk samples were found to be around 4.82 to 6.31%. The commercialized plain yogurt for 100 g serving size contains around 2.2 to 4.8%. As for carbohydrate, the compositions in the raw goat milk samples were quite high which were from 7.12 to 9.15% compared to the standard composition in the commercialized yogurt of around 3.5 to 4.2 %. Some adjustment needs to be done in order to get the protein and carbohydrate content within the composition range as in the standard plain yogurt.

Table 8: The standard compositions of plain yogurts by different commercialized brands/companies.

No	Company name	Serving size (g)	Chemical Composition in 100ml milk (%)		
			Fat	Protein	Carbohydrate
1	Redwood Hill Farm	170	10.0	17.0	6.0
2	Liberte	175	7.0	7.4	5.0
3	Meredith Black	100	4.8	4.2	4.2
4	Glenisk	150	0.0	10.0	4.0
5	Capretta	170	4.0	24.0	3.0
6	Hewitt's Dairy	175	9.0	-	4.0
7	Bellwether Farms	170	10.0	-	3.0
8	St Helen's Farm	150	0.1	6.0	4.3
9	Karla's Village	100	4.0	3.8	4.5
10	Delemere Dairy	100	5.9	2.2	3.9
11	Straus Family Creamery	227	18.0	-	5.0
12	Trader Joe	170	7.0	15.0	3.0
13	Voskos	227	31.0	19.0	5.0
14	Chobani	150	9.0	26.0	2.0
15	Oak Knoll Dairy	170	8.0	-	3.0
16	Skotidakis	150	5.0	-	4.0
17	Bergerie	100	5.9	5.8	3.5
18	Skyhill Napa Valley	170	11.0	-	3.0
19	Montchevre	141	2.8	7.8	4.3
20	Coach Farm	227	14.0	-	2.0

Overall, it can be summarized that the goat milk's chemical compositions need some adjustment in order to follow the standard composition of the commercialized plain yogurt. Chemical composition of the raw goat's milk can be adjusted by mixing the milk with skimmed milk and water. Besides, increasing the serving size for the yogurt will alter the value of all the three chemical compositions. Thus, the serving size selection also needs to be considered carefully.

4.0 CONCLUSION

This study has shown that chemical composition of milk can be detected by measuring the dielectric properties, given suitable frequency and temperature of the milk was known. The value of dielectric constant and dielectric loss factor of goat's milk were influenced by the chemical composition of the goat's milk. The dielectric constant decreased linearly with increasing of chemical composition at 915 MHz. By producing regression mathematical models at constant temperature, the value of chemical content can be calculated. This calculation can be used for fat, protein and carbohydrate content detector in milk. For a standardized samples of raw goat's milk that were being tested, all three chemical compositions of fat, protein and carbohydrate need to be reduced to get the same result as the standard from the available commercialized plain yogurt.

Acknowledgements

This research work was sponsored and supported by Universiti Teknologi Malaysia through Research University Grant No. Q.J130000.3552.05G50

References

[1] Lee, W.J., and Lucey, J.A. 2010. Formation and Physical Properties of Yogurt. *Asian-Australasian Journal of Animal Sciences* 23(9): 1127-1136.
[2] Ozer B.H. and Robinson R.K. 1999. What do you know about milk? (Milk Chemistry and Technology). Tehran: Agricultural Science Publishing.
[3] Shaker P.R., Jumah R.Y., Abu-Jdayil B. 2000. Reheological properties of plain yogurt during coagulation process: Impact of fat content and preheat treatment of milk. *Journal of Food Engineering* 44: 175-180.
[4] Walstra P., Wouters J.T.M., Geurts T.J. 2006. Chapter 7 Heat treatment. In Dairy Science and Technology; Taylor & Francis Group, LLC: Boca Raton, Fl, USA; 225-272.
[5] Xinhua Zhu, Wenchuan Guo, Yuanpeng Jia, Fei Kang. 2014. Dielectric properties of raw milk as function of protein content and temperature. *Food and Bioprocess Technology* (2015) 8:670–680.
[6] Xinhua Zhu, Wenchuan Guo, Zhibin Liang. 2015. Determination of the Fat Content in Cow Milk Based on Dielectric Properties. *Food and Bioprocess Technology*. 8(7): 1485-1494.