Food Science and Applied Biotechnology, 2021, **4**(1), 86-91

UFT Academic Publishing House, Plovdiv

Food Science and Applied Biotechnology
e-ISSN: 2603-3380

Journal home page: www.ijfsab.com
https://doi.org/10.30721/fsab2021.v4.i1

OPEN ACCESS

Short Communication

Effect of volume reduction ratio on the concentration and retention factors during ultrafiltration of goat's milk

Siyka Kodinova[1]✉, Mariya Dushkova[1]

[1]*Department of Process engineering, Technical Faculty, University of Food Technologies, Plovdiv, Bulgaria*

Abstract

This experimental work aimed to study the effect of volume reduction ratio on the concentration and retention (selectivity) factors during ultrafiltration of goat's milk with UF25-PAN polyacrylnitrile membrane. They were calculated on the basis of dry matter, total protein, fat and ash content in retentates and permeate at volume reduction ratios of 2 and 3. The results showed that the increase in the volume reduction ratio from 2 to 3 led to an increase in the concentration factors of dry matter - from 1.34 ± 0.05 to 1.87 ± 0.03, total proteins – from 1.70 ± 0.02 to 2.72 ± 0.06, fat – from 1.71 ± 0.03 to 2.71 ± 0.03, ash – from 1.13 ± 0.02 to 1.52 ± 0.02 ($p < 0.05$). At these conditions, the retention factor (selectivity) of ash increased from 37.40 ± 2.19% to 53.50 ± 2.21% ($p < 0.05$). There was no significant difference ($p > 0.05$) of the selectivity of the membrane according to the proteins when volume reduction ratio increased. The results showed that these two volume reduction ratios and this membrane could be successfully used for the production of yoghurts with improved quality making them an excellent functional food.

Keywords: ultrafiltration, concentration factor, retention factor, goat's milk

Abbreviations: ultrafiltration polyacrylonitrile membrane with molecular weight cut-off 25 kDa (UF25-PAN); volume reduction ratio (VRR)

✉*Corresponding author: Chief Assist. Professor Siyka Kodinova, PhD; Department of Process Engineering, Technical Faculty, 26 Maritza blvd. BG-4002 Plovdiv, Bulgaria, tel.: ++359 32 603 874; E-mail: sisi.kozludjova@abv.bg*

Article history:
Received 16 December 2020
Reviewed 11 January 2021
Accepted 23 February 2021
Available on-line 19 March 2021

https://doi.org/10.30721/fsab2021.v4.i1.135
© 2021 The Authors. UFT Academic publishing house, Plovdiv

Introduction

In recent years, more attention has been paid on the development and consumption of functional foods. These products are fortified, enriched or enhanced with components providing health benefits when they are consumed at efficacious levels (Brasil et al. 2011). After cow's milk, goat's and sheep's milks are the two basic milks produced, consumed and used in the production of dairy products (Silva and Costa 2019). Goat's milk has many essential components, especially proteins with high biological quality, nutritional and functional properties (emulsifying, foaming and gelling). It is a good source of vitamins, minerals like calcium, phosphorus, riboflavin and medium-chain fatty acids (Bergilos-Meca et al. 2015; Clark and García 2017; Verruck et al. 2019). Goat's milk can be used in the production of many dairy products, such as beverages, yoghurt, condensed milk, cheese, ice cream, buttermilk, butter, flavored milk (Aryana and Olson 2017; Fazilah et al. 2018; Miller and Lu 2019; Pal et al. 2017; Sepe and Argüello 2019).

Concentration, purification and fractionation of milk components can be carried out by means of membrane processes where ultrafiltration takes the first place (Chen et al. 2019; Zhang et al. 2020). Membrane filtration processes which use a hydrostatic pressure to force low-molecular components through a semi-permeable membrane are well known as ultrafiltration, nanofiltration and reverse osmosis (Reis et al. 2007). Ultrafiltration is preferred concentration method in comparison with the conventional evaporation due to the following advantages – low energy costs, novel non thermal environmentally friendly technology that minimizes the adverse effect of temperature rise such as change in phase and denaturation of proteins (Ali et al. 2017; He and Hägg 2012; Macedonio and Drioli 2017; Kumar et al., 2013).

Retention factor (selectivity) is the qualitative characteristic of ultrafiltration process which generally determines the effectiveness of membrane concentration (Fang et al. 2015; Le et al. 2014; Polyakov and Zydney 2013). The successful application of ultrafiltration depends on the knowledge about factors which affect the process such as the type and pore size of the membrane, operating conditions as well as the interactions between the membrane and the feed solution (Tamime 2013). The concentration of goat's milk by ultrafiltration is one of the most promising research areas for the modern goat's dairy industry (Verruck et al. 2019).

The aim of the experimental work was to study the effect of volume reduction ratio on the concentration and retention (selectivity) factors during ultrafiltration of goat's milk with UF25-PAN polyacrylnitrile membrane.

Materials and Methods

Milk. The experimental work was carried out with commercially purchased whole goat's milk Olympus (Bulgaria).

Membrane. UF25-PAN polyacrylonitrile membrane with molecular weight cut-off of 25 kDa was used for the experimental work. The membrane was prepared by dry-wet phase-inversion method of polymer solution with dimethyl formamide as solvent (Sigma Aldrich, Germany). Then it was heat-treated in aqueous medium for 10 min at 80°C.

Ultrafiltration equipment. Ultrafiltration experiments were carried out on laboratory equipment with a replaceable plate and frame membrane module fitted with UF25-PAN polyacrylonitrile membrane shown on Fig. 1. This equipment contained a plate and frame membrane module with membrane surface area of 0.125 m^2, a three-plunger high-pressure pump (max 15 MPa) with a capacity of 330 $dm^3.h^{-1}$; a pipeline system with two manometers (0 MPa to 15 MPa) for measuring the inlet and outlet pressure; and a special working pressure regulating valve. Ultrafiltration was carried out under the following operating conditions: working pressure of 0.2 MPa, temperature of 20°C and volume reduction ratios of 2 and 3. All experiments were carried out at a feed flow rate of 330 $dm^3.h^{-1}$.

Physicochemical analysis. In all experiments, samples of the initial goat's milk, ultrafiltration retentates obtained at volume reduction ratios of 2 and 3, as well as ultrafiltration permeate were taken. They were analyzed according to dry matter content (ISO 6731:2010), fat content (ISO 2446:2008), total protein content (ISO 8968-1:2014), ash content (BSS 6154:1974). The physicochemical indices were performed in triplicate.

Figure 1. Scheme of laboratory equipment with a replaceable plate and frame membrane module 1 – valve; 2, 3, 4 – manometers; 5 – replaceable plate and frame membrane module; 6 – pump; 7 - tank for initial solution; 8 – cylinder for permeate

Calculation of volume reduction ratio (*VRR*). The volume reduction ratio (*VRR*) was calculated by the following formula:

$$VRR = V_0/V_R \quad (1)$$

where: V_0, dm^3 was the volume of the initial milk and V_R, dm^3 was the volume of the retentate.

Determination of concentration and retention factors. Concentration factor was calculated as follows:

$$CF = C_R/C_O \quad (2)$$

where: C_R, % and C_O, % were the dry matter, fat, total protein or ash content in ultrafiltration retentates and initial goat's milk.

The retention factor (selectivity) was calculated as follows:

$$R = (1 - C_P/C_R)\times 100, \% \quad (3)$$

where: C_p, % and C_R, % were the protein or ash content in ultrafiltration permeate and retentates, respectively.

Statistical analysis. Fisher's least significant difference test at a significance level of 0.05 was used for the comparison of the experimental values using Excel 2010 by a one-way analysis of variance (one-way ANOVA).

Results and Discussion

The chemical composition (dry matter, fat, total protein and ash content) of initial goat's milk and ultrafiltration retentates at volume reduction ratios of 2 and 3 during ultrafiltration of goat's milk with UF25-PAN membrane, as like as permeate, are presented in Table 1. It could be seen that the increase in volume reduction ratio led to an increase ($p < 0.05$) in the dry matter content from 12.30 ± 0.26% to 23.00 ± 0.15%, the total proteins – from 3.53 ± 0.10% to 9.60 ± 0.05%, the fat content – from 3.5 ± 0.10% to 9.50 ± 0.20 %, the ash content – from 0.87 ± 0.02% to 1.32 ± 0.03%. This was probably due to the molecular weight cut-off of the membrane used in this experimental research and its ability to maintain high molecular weight components, such as proteins and milk fat, and to allow the passage of low molecular weight components, such as minerals and lactose. The proteins have molecular weight in the range from 14 kDa to 900 kDa, except proteose-peptones; the milk fat from 0.1 μm to 15 μm; the lactose – 350 Da; the minerals - up to 100 Da (Norazman et al. 2013; Iritani et al. 2014). According to Moreno-Montoro et al. (2015), the dry matter, total proteins and ash increased at volume reduction ratio of 1.7 with 50 kDa ultrafiltration membrane. Domagala and Kupiec (2003) studied the composition of retentates from goat's milk at 2-fold ultrafiltration concentration with three various membranes (10 kDa, 30 kDa and 100 kDa) and found an increase in the total solids, proteins, fat, ash, and a decrease in the lactose content with all membranes investigated. Meena et al. (2015) determined the highest increase in the total solids, fat, proteins, ash and the highest decrease in the lactose content in the 3.87 fold retentate in comparison with 1.55 and 1.28 fold retentates from buffalo's milk with 50 kDa ultrafiltration membrane.

The concentration and retention factors of the main components at volume reduction ratios of 2 and 3 are presented in Table 2. The results showed that the concentration factor of the dry matter increased from 1.34 ± 0.05 at *VRR* = 2 to 1.87 ± 0.03 at *VRR* = 3 ($p < 0.05$). At the same time, the protein concentration factor increased from 1.70 ± 0.02 to 2.72 ± 0.06, respectively ($p < 0.05$), fat concentration factor – from 1.71 ± 0.03 to 2.71 ± 0.03 ($p < 0.05$), ash – from 1.13 ± 0.02 to 1.52 ± 0.02 ($p < 0.05$). Our results are in agreement with the experimental work of Baldasso et al. (2011), Luo et al. (2015) and Macedo et al. (2012) which found that the concentration and retention factors increased with the increase in the volume reduction ratio for other types of milk. The results showed the possibility of the membrane and volume reduction ratios studied to concentrate the main components of goat's milk in order to be used for obtaining of yoghurts and to improve their quality. According to Moineau-Jean et al. (2019), the use of ultrafiltration of milk prior to fermentation led to a higher protein content which favoured the growth of *Lb. helveticus* R0052 and *S. thermophilus,* and increased the functionality of the final product. The experimental work of other researchers also proved the positive effect of ultrafiltration of milk to obtain high quality plain yoghurt, without addition of stabilizers, which is otherwise widely used commercially for the manufacture of yoghurt to control its wheying off and body (Narayana and Gupta 2016). In our experimental work, the retention factor of the ash increased from 37.40 ± 2.19% (*VRR* = 2) to 53.50 ± 2.21% (*VRR* = 3) ($p < 0.05$), while according to the total protein contents there was no signifficant difference between *VRR* = 2 and *VRR* = 3 ($p > 0.05$).

Table 1. Chemical composition of goat's milk, retentates at *VRR* = 2 and *VRR* = 3 and permeate

Indice	Average value ± SD
Goat's milk	
Dry matter, %	12.30 ± 0.26[a]
Total protein, %	3.53 ± 0.10[a]
Milk fat, %	3.5 ± 0.10[a]
Ash, %	0.87 ± 0.02[a]
Retentate at VRR = 2	
Dry matter, %	16.48 ± 0.90[b]
Total protein, %	6.01 ± 0.12[b]
Milk fat, %	6.00 ± 0.10[b]
Ash, %	0.98 ± 0.01[b]
Retentate at VRR = 3	
Dry matter, %	23.00 ± 0.15[c]
Total protein, %	9.60 ± 0.05[c]
Milk fat, %	9.50 ± 0.20[c]
Ash, %	1.32 ± 0.03[b]
Permeate	
Dry matter, %	5.19 ± 0.08[d]
Total protein, %	0.25 ± 0.09[d]
Ash, %	0.61 ± 0.02[d]

Note: Different lowercase letters (a, b, c, d) showed a significant difference between the composition of the initial goat's milk, retentates at volume reduction ratios of 2 and 3, and permeate ($p < 0.05$).

Table 2. Concentration (*CF*) and retention (*R*, %) factors at *VRR* = 2 and *VRR* = 3

Indice	Average value ± SD
Retentate at VRR = 2	
Concentration factor of dry matter	1.34 ± 0.05[a]
Concentration factor of total protein	1.70 ± 0.02[a]
Retention factor of total protein, %	95.86 ± 0.42[a]
Concentration factor of milk fat	1.71 ± 0.03[a]
Concentration factor of ash	1.13 ± 0.02[a]
Retention factor of ash, %	37.40 ± 2.19[a]
Retentate at VRR = 3	
Concentration factor of dry matter	1.87 ± 0.03[b]
Concentration factor of total protein	2.72± 0.06[b]
Retention factor of total protein, %	97.40 ± 0.92[a]
Concentration factor of milk fat	2.71 ± 0.03[b]
Concentration factor of ash	1.52 ± 0.02[b]
Retention factor of ash, %	53.50 ± 2.21[b]

Note: Different lowercase letters (a and b) showed a significant difference between the concentration or retention factors at volume reduction ratios of 2 and 3 ($p < 0.05$).

Conclusions

The increase in the volume reduction ratio from 2 to 3 during ultrafiltration of goat's milk with UF25-PAN membrane led to an increase ($p < 0.05$) in the dry matter content from 12.30 ± 0.026% to 23.00 ± 0.15%, the total proteins – from 3.53 ± 0.10% to 9.60 ± 0.05%, the milk fat – from 3.5 ± 0.10% to 9.50 ± 0.20%, the ash – from 0.87 ± 0.02% to 1.32 ± 0.03%. At these conditions, the concentation factors of dry matter, fat, total proteins and ash increased. Similar results were obtained for the retention factor of ash, while according to the total proteins there was no statistically signifficant difference between volume reduction ratio 2 and 3. These volume reduction ratios and UF25-PAN membrane can be used for the production of yoghurts.

Acknowledgements

The authors acknowledge the financial support provided by Fund „Science" (Contract 08/19-H) at the University of Food Technologies, Bulgaria.

References

Ali A, Drioli E, Macedonio F. Membrane engineering for sustainable development: A perspective. *Applied Science*, 2017, 7(10), 1026. https://doi.org/10.3390/app7101026

Aryana KJ, Olson DW. A 100-year review: Yogurt and other cultured dairy products. *Journal of Dairy Science*, 2017, 100(12), 9987-10013. https://doi.org/10.3168/jds.2017-12981

Baldasso C, Barros TC, Tessaro IC. Concentration and purification of whey proteins by ultrafiltration. *Desalination*, 2011, 278(1-3), 381-386. https://doi.org/10.1016/j.desal.2011.05.055

Bergillos-Meca T, Cabrera-Vique C, Artacho R, Moreno-Montoro M, Navarro-Alarcón M, Olalla M, Giménez R, Seiquer I, Ruiz-López M.D. Does *Lactobacillus plantarum* or ultrafiltration process improve Ca, Mg, Zn and P bioavailability from fermented goat's milk? *Food Chemistry*, 2015, 187(11), 314-321. https://doi.org/10.1016/j.foodchem.2015.04.051

Brasil J, Silveira K, Salgado S, Livera A, De Faro Z, Guerra N. Effect of the addition of inulin on the nutritional, physical and sensory parameters of bread. *Brazilian Journal of Pharmaceutical Science*, 2011, 47(1): 185-191. https://doi.org/10.1590/S1984-82502011000100023

Chen, G. Q., Leong, T. S. H., Kentish, S. E. Ashokkumar, M., Martin, G. J. O. Membrane Separations in the Dairy Industry. In: *Separation of Functional Molecules in Food by Membrane Technology* (Charis Galanakis Ed.). Academic Press. 2019, pp. 5-120. ISBN 978-0-12-815056-6 https://doi.org/10.1016/B978-0-12-815056-6.00008-5

BSS 6154:1974. Methods for determination of ash content. Sofia, Bulgaria: The Bulgarian Institute of Standardization, 1974 [in Bulgarian]. https://www.bds-bg.org

Clark, S., García, M. B. A 100-year review: Advances in goat milk research. *Journal of Dairy Science*, 2017, 100(12), 10026-10044. https://doi.org/10.3168/jds.2017-13287

Domagala, J., Kupiec, B. E. Changes in texture of yoghurt from ultrafiltered goat's milk as influenced by different membrane types. *Electronic Journal of Polish Agricultural Universities*, 2003, 6(1), #05. http://www.ejpau.media.pl/volume6/issue1/food/art-05.html

Fang X, Li J, Li X, Sun X, Shen J. Polyethylenemine, an effective additive for polyetherosulphone ultrafiltration membrane with enhanced permeability and selectivity. *Journal of Membrane Science*, 2015, 476(2), 216-223. https://doi.org/10.1016/j.memsci.2014.11.021

Fazilah NF, Ariff AB, Khayat ME, Rios-Solis L, Halim M. Influence of probiotics, prebiotics, synbiotics and bioactive phytochemicals on the formulation of functional yogurt. *Journal of Functional Foods*, 2018, 48(9), 387-399. https://doi.org/10.1016/j.jff.2018.07.039

He X, Hägg M-B. Membranes for environmentally friendly energy processes. *Membranes*, 2012, 2(4), 706-726.https://doi.org/10.3390/membranes2040706

Iritani E, Katagiri N, Ishikawa Y, Cao DQ. Cake formation and particle rejection in microfiltration of binary mixtures of particles with two different sizes. *Separation and Purification Technology*, 2014, 123(2), 214-220. https://doi.org/10.1016/j.seppur.2013.12.033

ISO 6731:2010. Milk, cream and evaporated milk – Determination of total solids content (Reference method). Geneva, Switzerland: International Organization for Standardization (ISO), 2010. https://www.iso.org/standard/56815.html

ISO 8968-1:2014. Milk and milk products – Determination of nitrogen content – Part 1: Kjeldahl principle and crude protein calculation. International Organization for Standardization (ISO), 2014. https://www.iso.org/standard/61020.html

ISO 2446:2008. Determination of fat content. International Organization for Standardization (ISO), 2008. https://www.iso.org/standard/51019.html

Kumar P, Sharma N, Ranjan R, Kumar S, Bhat Z, Jeong D. Perspective of membrane technology in dairy industry: A review. *Asian-Australasian Journal of Animal Sciences*, 2013, 26(9), 1347-1358. https://doi.org/10.5713/ajas.2013.13082

Le TT, Cabaltica AD, Bui V-M. Membrane separations in dairy processing. *Journal of Food Research and Technology*, 2014, 2(1), 01-14. Available at: http://www.jakraya.com/journal/pdf/3-jfrtArticle_1.pdf

Luo X, Ramchandran L, Vasiljevic T. Lower ultrafiltration temperature improves membrane performance and emulsifying properties of milk protein concentrates. *Dairy Science and Technology*, 2015, 95(1), 15-31. https://doi.org/10.1007/s13594-014-0192-3

Macedo A, Pinho M, Duarte E. Application of ultrafiltration for valorization of ovine cheese whey. *Procedia Engineering*, 2012, 44(1), 1949-1950. https://doi.org/10.1016/j.proeng.2012.09.005

Macedonio F, Drioli E. Membrane engineering for green process engineering. *Engineering*, 2017, 3(3), 290-298. https://doi.org/10.1016/J.ENG.2017.03.026

Meena PK, Gupta VK, Meena GS, Raju PN, Parmar PT. Application of ultrafiltration technique for the quality improvement of Dahi. *Journal of Food*

Science and Technology, 2015, 52(12), 7974-7983. https://doi.org/10.1007%2Fs13197-015-1951-8
Milller BA, Lu CD. Current status of global dairy goat production: An overview. *Asian-Australas Journal of Animal Science*, 2019, 32(8), 1219-1232. https://doi.org/10.5713/ajas.19.0253
Moineau-Jean A, Champagne CP, Roy D, Raymond Y, La Pointe G. Effect of Greek - style yoghurt manufacturing processes on starter and probiotic bacteria populations during storage. *International Dairy Journal*, 2019, 93(6), 35-44. https://doi.org/10.1016/j.idairyj.2019.02.003
Moreno - Montoro, M., Olalla, M., Giménez - Martínez, R., Bergillos - Meca, T., Ruiz - López, M., Cabrera - Vique C, Artacho R, Navarro-Alarcón M. Ultrafiltration of skim goat's milk increases its nutritional value by concentrating nonfat solids such as proteins, Ca, P, Mg, and Zn. *Journal of Dairy Science*, 2015, 98(11), 7628-7634. https://doi.org/10.3168/jds.2015-9939
Narayana NMNK, Gupta VK. Quality of plain set yoghurt as affected by levels of ultrafiltration concentration of milk and inoculum of yoghurt culture. *Turkish Journal of Agriculture - Food Science and Technology*, 2016, 4(6), 508-514. https://doi.org/10.24925/turjaf.v4i6.508-514.685
Norazman, N., Wu, W., Li, H., Wasinger, V., Zhang, H., Chen V. Evaluation of chemical cleaning of UF membranes fouled with whey protein isolates via analysis of residual protein components on membranes surface. *Separation and Purification Technology*, 2013, 103(1), 241-250. https://doi.org/10.1016/j.seppur.2012.10.039
Polyakov YS, Zydney AL. Ultrafiltration membrane performance: Effects of pore blockage/constriction. *Journal of Membrane Science*, 2013, 434(5), 106-120. https://doi.org/10.1016/j.memsci.2013.01.052
Pal M, Dudhrejiya TP, Pinto S. Goat milk products and their significance. *Beverage and Food World*, 2017, 44(7), 21-25.
Reis R, Zydney AL. Bioprocess membrane technology. *Journal of Membrane Science*, 2007, 297(1-2), 16-50. https://doi.org/10.1016/j.memsci.2007.02.045
Sepe L, Argüello A. Recent advances in dairy goat products. *Asian-Australas Journal of Animal Science*, 2019, 32(8), 1306-1320. https://doi.org/10.5713/ajas.19.0487
Silva VB, Da Costa MP. Influence of processing on rheological and textural characteristics of goat and sheep milk beverages and methods of analysis. *Processing and Sustainability of Beverages*, 2019, 2(The Science of Beverages), 373-412. https://doi.org/10.1016/B978-0-12-815259-1.00011-2
Tamime AY. Development of membranes processes. In: *Membrane Processing: Dairy and Beverage Applications* (AY Tamime Ed.). Wiley-Blackwell. 2013, pp. 4-158. Print ISBN: 9781444333374, Online ISBN: 9781118457009 https://doi.org/10.1002/9781118457009
Verruck S, Dantas A, Prudencio ES. Functionality of the components from goat's milk, recent advances for functional dairy products development and its implications on human health. *Journal of Functional Foods*, 2019, 52(1), 243-257. https://doi.org/10.1016/j.jff.2018.11.017
Zhang H, Tao J, He Y, Pan J, Jang K, Shen J, Gao C. Preparation of low-lactose milk powder by coupling membrane technology. *ACS Omega*, 2020, 5(15), 8543-8550. https://doi.org/10.1021/acsomega.9b04252