ABOUT AJFS

The African Journal of Food Science (AJFS) (ISSN 1996-0794) is published monthly (one volume per year) by Academic Journals.

African Journal of Food Science (AJFS) provides rapid publication of articles in all areas of Food Science such as Sensory analysis, Molecular gastronomy, Food safety, Food technology etc. The Journal welcomes the submission of manuscripts that meet the general criteria of significance and scientific excellence. Papers will be published shortly after acceptance. All articles published in AJFS are peer-reviewed.

Contact Us

Editorial Office: ajfs@academicjournals.org
Help Desk: helpdesk@academicjournals.org
Website: http://www.academicjournals.org/journal/AJFS
Submit manuscript online http://ms.academicjournals.me/
Editors

Dr. Thaddeus Chukwuemeka Ezeji
Ohio State University and
Ohio State Agricultural and Development
Center (OARDC)
Department of Animal Sciences
USA.

Prof. Kofi E. Aidoo
Department of Biological and Biomedical
Sciences
Glasgow Caledonian University
Glasgow
Scotland.

Dr. Barakat S.M. Mahmoud
Food Safety/Microbiology
Experimental Seafood Processing Laboratory
Costal Research and Extension Centre
Mississippi State University
USA.

Dr. Neela Badrie
Department of Food Production,
Faculty of Science and Agriculture,
University of the West Indies,
Trinidad and Tobago.

Dr. Hu Xiao-Qing
State Key Lab of Food Science and Technology,
Jiangnan University,
China.

Dr. Dominic Agyei
Department of Food Science/Te Tari Pütaiao Kai
University of Otago,
Dunedin,
New Zealand.

Dr. Fook Yee Chye
Faculty of Food Science and Nutrition,
Universiti Malaysia Sabah,
Malaysia.

Dr. Adel Shatta
Department of Food Technology,
Faculty of Agriculture,
Egypt.

Dr. Tendekayi Henry Gadaga
Department of Environmental Health Science
University of Swaziland
Swaziland.
Editorial Board Members

Dr. K. Pandima Devi
Department of Biotechnology
Alagappa University
Tamil Nadu
India.

Dr. Ashish Kumar Singh
Dairy Technology Division
National Dairy Research Institute,
Haryana,
India.

Prof. Rui Cruz
Department of Food Engineering
Institute of Engineering
University of Algarve, Faro
Portugal.
| Title                                                                 | Page |
|----------------------------------------------------------------------|------|
| Influence of temperature and time on microbial, physicochemical and functional quality of goat milk | 86   |
| Ibrahim Aldaw Ibrahim, Rifda Naufalin, Erminawati Wuryatmo, Hidayah Dwiyanti and Shima Esameldin Hamouda |      |
| Effects of processing methods on fatty acid profiles and biochemical compounds of Arabica coffee cultivars | 92   |
| Richard Kipkorir Koskei, Beatrice Mugendi and Patrick Muliro         |      |
| Sensory evaluation of four pepper soup dishes prepared with four varieties of protein sources using Itsekiri pepper soup spices | 98   |
| Keswet Larai A. and Abia Florence O.                                 |      |
| Effect of different processing conditions on the quality of canned sweet corn kernels produced and processed in Senegal | 102  |
| Nafissatou DIOP NDIAYE, Adjaratou BASSE DIENG and Thomas L. THOMPSON   |      |
Influence of temperature and time on microbial, physicochemical and functional quality of goat milk

Ibrahim Aldaw Ibrahim1,2, Rifda Naufalin1*, Erminawati Wuryatmo1, Hidayah Dwiyanti1 and Shima Esameldin Hamouda2

1Department of Food and Technology, Faculty of agriculture, Universitas Jenderal Soedirman, Purwokerto, Indonesia.
2Department of Food Science and Technology, Faculty of Agriculture, Omdurman Islamic University, Khartoum, Sudan.

Received 30 January, 2020; Accepted 2 April, 2020

Microbial load in fresh milk has a significant effect on its keeping quality and nutritional value. From Prehistoric time, human used heat process to reduce microbials load in raw milk to improve its sensory characteristics. This research is proposed to treat fresh goat milk with heating process to provide optimal pasteurization conditions that does not influence the goat milk chemical composition to suite production of goat yogurt powder. The pasteurization conditions considered were: Temperature (72, 80, and 85°C) and time (5, 10 and 15s). These results showed there were a significant difference (P<0.05) between treated milk and Indonesia national standards on viscosity and pH; whereas there was no significant differences on density and titratable acidity. The study results concluded that the temperature and time during heat processing had a significant effect on nutritional compounds of goat milk, with increase in lactose and non-fat solids contents; therefore, treated goat milk at 85°C to 5 s is better than other treatments.

Key words: Goat’s milk, pasteurization, physicochemical analysis, microbiology.

INTRODUCTION

Milk is a good food in human diet. It is a source of nutrients such as vitamins, protein, fat, water, lactose, and essential minerals. It contains minerals, enzymes and vitamins as secondary constituents (Contreras et al., 2015; Raikos, 2010; Pereira, 2014; Mcmahon, 2013; Guetouache et al., 2014). Goat's milk contains a higher amount of minerals than cow and human milks, such as magnesium, calcium and phosphorus (Abbas et al., 2014). Moreover, it contains several nutrients and therapeutic properties as a functional diet for human health. It's important for prevention of diseases, and used for stimulation of immunity (Vargas et al., 2008; Zenebe et al., 2014; Kumar et al., 2012). Goat’s milk has a higher digestibility and less sensitivity digestion than cow’s milk, as well as a higher content of short-chain fatty acids in milk fat, high zinc and iron content magnesium and antibacterial properties (Slacanac et al., 2010; Guowei et al., 2016). Microbial growth has been reported to impact negatively on the physicochemical characteristics, shelf life of raw and processed milk as well as in other dairy products (Samaržija et al., 2010). Heat processing is the oldest
methods used to treat dairy products; it is applied to reduce microbial load in raw milk and improving sensory properties of milk compounds. Thus, it is considered as a very effective and simple method. In addition, it has a positive effect on sensory and nutritional values of milks and dairy products (Pedras et al., 2012; Raikos, 2010; Vargas, 2016).

The high temperature for long time processing of milk leads to more reduction of the amount of water, leading to increase in total solids. Moreover, heat treatment of milk up to 80°C for 15s leads to less nutritional minerals such as calcium (Sestan et al., 2016). Pasteurization is capable of reducing a count of microbial load in raw milk, which is important to extend the shelf life of milk. On the other hand, they have no influence on milk composition and fatty acid profile (Pestana et al., 2015; El-Zubeir et al., 2007).

Pasteurization is one of the processing used to reduce microbial load and extend the shelf life of the milk. However, it affects milk compounds and decreases the milk nutritional values. It has negative effect on loss of some vitamins with changing in nutritional and sensory properties (Cavalcante et al., 2013; Aguirre et al., 2009; Abd Elrahman et al., 2013). The study investigated the effect of pasteurization temperature and time on microbial and physicochemical quality of goat’s milk and its outcome on lactose and non-fat solids level.

**MATERIALS AND METHODS**

**Sample collected**

Goat’s milk samples, Perankan Etawa, were purchased from Baturaden Animal Farm, Purwokertow, Central Java, Indonesia. Then samples were stored in freezer at -80°C for subsequent processing.

**Heat processing**

A half liter (500ml) for each goat milk samples were weighted and put separately in a pot. Milk samples were coded from Y1 to Y9 as treated milk and Y10 as a control. Milk samples were put in pots and heated at different temperatures (72, 80 and 85°C) at different times (5, 10 and 15 s). The milk samples were treated according to methods (Zhao, 2016; Miao, 2011; Wu et al., 2016; Ibrahim et al., 2019).

**Physicochemical analysis**

The goat milk samples were analyzed for the chemical compositions using a lactoscan analyzer. The compositional parameters evaluated were: Physical and chemical characteristics of heated milk as (total solid (TS), pH, titratable acidity (TA), density (25°C), viscosity (25°C), and color. The density was determined according to (SNI: 06- 2385-2006), official method 920.212. The viscosity was determined according to AOAC (2005). The color parameters were determined using a minolta CM-2002 spectrophotometer (minolta camera Co., osaka, Japan) in the reflection mode, using the method of (Chugh et al., 2014; Bermúdez-Aguirre et al., 2009), according to color measured. Lightness to darkness (L*) (100 to 0), redness (+) to greenness (-) (a*), and yellowness (+) to blueness (-) (b*) 20 ml of raw and thermo-ultrasonicated. The total solid (TS) was determined according to the method of Almeida et al. (2010). The pH (AOAC, 2005) and the titratable acidity (TA) was determined according to AOAC (2005) method. The microbiology analysis of the samples, total plat count, yeasts, and moulds were determined according to method of Mohammad and El-Zubeir, (2011) as described by Igbabul et al. (2014). The media and distilled water and other tools were sterilized using autoclave, and using serial dilution to 10<sup>3</sup> to reduce the number of microorganisms in samples.

**Statistical analysis**

The analysis of variance (ANOVA) two-way tests was performed to evaluate the difference between data by using SPSS for Windows (version 16, SPSS, Inc., Chicago, IL) and Microsoft Excel (2013). The means were separated by Duncan Multiple range test. Significant differences were determined at (P<0.05).

**RESULTS AND DISCUSSION**

**Goat milk compositions**

The results obtained from Table 1 shown compositions content of fresh goat milk. Fresh goat milk sample analysis by lactoscan showed that the fat content was 6.67%. This result shows that fresh goat milk has a higher fat content than cow milk; thus, it has better taste and aroma in final yogurt production. This result agrees with Indonesian National Standards (2008), and disagrees with Yusa et al. (2017), who reported that the fresh goat milk fat content was 4.5% and pasteurized goat milk was 5%. This difference in fat content is due to animal type, age, race, season, environment, and feeds. Specific gravity value was 21.41%; this result is lower than cow milk specific gravity. These results showed significant difference with Standard National Indonesian (SNI) (2011) in specific gravity, this difference is due to water content in milk. The high amount of water in milk decreases specific gravity and other milk compositions. The non-fat solids values were 6.81%; this result is lowest in cow milk having non-fat solids, and disagrees with TAS (2008). The lactose value obtained was 3.26%; this result showed that the lactose content of fresh goat milk is lower than cow milk and not in range of standards. TAS (2008) it reported the lactose content of milk was minimum 4.5% and non-fat solids was 7.8%; this difference is due to animal type, age, race, season, environment, and feeding.

**Effect of pasteurization on fresh goat milk compositions**

The protein results showed that in Table 2, from these results obtained, the protein content (%) of sample Y1
was 2.97 is higher than other samples, and protein value in sample Y6 was 2.59, which is lowest in protein content. The results obtained from each samples showed significant difference with control sample and SNI (2011), which reported that the goat milk protein contains between 3.1-3.2, fat contain is 3.25-3.5, and total solid is 11.7-12. This difference is due to temperature and time, which have significant effect on decreased fresh goat milk protein level. This decrease in level of protein with increase pasteurization temperature is due to concomitant decrease in moisture, hence the increase in level of protein denaturation. These results are consistent with Hamodah et al. (2018), Aguirre et al. (2009) but disagrees with Abdelrahman et al. (2013), who mentioned that pasteurizing milk can decrease nutritional values of milk such as protein content, pH and density. Also, from the results, it increase the butter fat and titratable acidity in milk, and this is in agreement with Ul Hag et al. (2013), who mentioned that pasteurization and sterilization processes revealed significant influence on pH, titratable acidity, specific gravity, lactose, fat, protein and ash content of milk and skimmed milk.

The fat content was higher in Sample Y1, 6.65% and lowest in Y3, 5.57%. This result showed that fat content is lower than control and higher than indonesian national standard. From these results, the pasteurization has significant effect on decrease fat content of fresh goat milk. This decrease in fat content is due to effect of pasteurization temperature on oxidation of milk fat; thus, leading to breaking up of the clumps or clusters of fat in raw milk, and consequently, decrease fat content in treated milk. These results are in agreement with Elhasan et al. (2017), Mohammad et al. (2017), and disagrees with Li et al. (2018), who mentioned that pasteurization treatment is capable to reduce microbial load in fresh milk. However, it is not effective on levels of oxidation in lipids and without significant changes in the milk pH. This is in agreement with some studies (Cavalcante et al., 2013; Aguirre et al., 2009; Abd Elrahman et al., 2013) that reported that Pasteurization is one of the treatments used to reduce microbial load and prolong the shelf life of raw milk. It has positive effect on milk compounds and decrease nutritional values of milk. However, it has loss of some vitamins with change in nutritional and sensory properties.

The non-fat solids are highest in Y3 sample was 8.06%, and showed lowest in sample Y1, 7.1%. From these results, there were significant difference (P<0.05) between all treated milk samples with control. This results shows that pasteurization has significant effect on

### Table 1. Goat milk compositions.

| Parameter         | Values (%) |
|-------------------|------------|
| Fat               | 6.67       |
| Specific gravity  | 21.41      |
| Lactose           | 3.26       |
| Non-fat solids    | 6.81       |
| Protein           | 3.22       |
| Added water to milk | 25.54     |
| Freezing point    | -0.384     |

### Table 2. Effect of pasteurization on goat milk compositions.

| Parameter   | Fat   | Specific gravity | Lactose | Solids non-fat | Protein |
|-------------|-------|------------------|---------|----------------|---------|
| Y1          | 6.65<sup>a</sup> | 22.49<sup>b</sup> | 3.89<sup>b</sup> | 7.10<sup>b</sup> | 2.97<sup>a</sup> |
| Y2          | 6.47<sup>ab</sup> | 25.33<sup>ab</sup> | 4.19<sup>ab</sup> | 7.65<sup>ab</sup> | 2.89<sup>ab</sup> |
| Y3          | 5.57<sup>d</sup> | 24.78<sup>ab</sup> | 4.41<sup>a</sup>  | 8.06<sup>a</sup> | 2.61<sup>b</sup> |
| Y4          | 6.21<sup>b</sup> | 25.43<sup>ab</sup> | 4.23<sup>ab</sup> | 7.73<sup>ab</sup> | 2.84<sup>ab</sup> |
| Y5          | 6.02<sup>b</sup> | 26.40<sup>a</sup>  | 4.36<sup>a</sup>  | 7.98<sup>a</sup> | 2.66<sup>b</sup> |
| Y6          | 5.73<sup>ab</sup> | 23.44<sup>bc</sup> | 4.39<sup>a</sup>  | 7.99<sup>a</sup> | 2.60<sup>b</sup> |
| Y7          | 6.47<sup>ab</sup> | 25.96<sup>a</sup>  | 4.31<sup>a</sup>  | 7.84<sup>ab</sup> | 2.89<sup>ab</sup> |
| Y8          | 5.96<sup>b</sup> | 24.52<sup>ab</sup> | 4.28<sup>ab</sup> | 7.85<sup>ab</sup> | 2.88<sup>ab</sup> |
| Y9          | 5.75<sup>d</sup> | 25.57<sup>a</sup>  | 4.29<sup>ab</sup> | 7.86<sup>a</sup> | 2.87<sup>d</sup> |
| Y10         | 6.67<sup>a</sup> | 21.41<sup>de</sup> | 3.26<sup>c</sup>  | 6.81<sup>c</sup> | 3.22<sup>c</sup> |

Y1 = 72°C/5s, Y2 = 72°C/10s, Y3 = 72°C/15s, Y4 = 80°C/5s, Y5 = 80°C/10s, Y6 = 80°C/15s, Y7 = 85/5s, Y8 = 85/10s, and Y9 = 5/15s, and Y10 as control.
increased non-fat solids. This difference in increasing non-fat solid due to the temperature effect on evaporated water from milk led to decreased water content, and change in nature of carbohydrate in milk. These results disagree with Abdelrahman et al. (2013), who mentioned that pasteurizing milk can decrease nutritional values of milk such as protein content. On the other hand, lactose content and specific gravity in each samples increased. In addition, the heat treatment increased non-fat solids, lactose and specific gravity values, and decreased the protein and fat content. This results is consistent with Hamodah et al. (2018) and Aguirre et al. (2009) and disagree with Abdelrahman et al. (2013), who mentioned that pasteurizing milk can decrease nutritional values of milk such as protein content, pH. Also, it increased the titratable acidity in milk, which is in agreement with Ul Hag et al. (2013) who mentioned that pasteurization and sterilization processes revealed significant influence on pH, titratable acidity, specific gravity, lactose, fat protein and ash content of milk.

Effect of heat processing on physicochemical properties of fresh goat milk

Table 3 showed effect of pasteurization on physical and chemical properties of fresh goat milk. The results obtained are presented in Table 3. Based on results obtained from milk analysis by lactoscan analyzer, it showed that the pH of Y1 was 6.6, Y2 was 6.5, Y3 was 6.4, Y4 was 6.3, Y5 was 6.3, Y6 was 6.2, Y7 was 6.6, Y8 was 6.4, and Y9 was 6.5. These results showed that the pH of Y3 is higher compared to other samples, and pH values of Y6 sample was lowest, 6.2. From these results there was significant difference between heated goat milk and control. These results show that pasteurization has significant effect on decreased pH value of fresh milk. The difference in pH value is due to effect of temperature and time on milk compounds. The density values of samples were 1.03, 1.03, 1.05, 1.08, 1.01, 1.04, 1.06, 1.05, 1.06 respectively. The result obtained shows that the density of Y4 is highest, and density value of Y5 sample is the lowest. These results showsignificant difference (P≤ 0.05) between Y4, Y9, Y7, Y8, Y3 and Y5; on the other hand, no significant difference (P≤ 0.05) between Y1, Y2 and control samples. The freeze point values were -0.460, -0.493, -0.539, -0.501, -0.519, -0.452, -0.510, -0.480, -0.511, and -0.384 as control sample respectively. These results showed significant difference (P≤ 0.05) between heat goat milk samples. These results indicate that the pasteurization has significant effect on pH decrease, density and freezing point, and increase of titratable acidity in goat milk. Conversely, there was no significant effect on titratable acidity. This result disagrees with Frau et al. (2014), and agrees others (Ul Hag et al., 2013; Elhasan et al., 2017). Wang et al. (2016) reported the different heat processes effect on milk properties, and agrees with Ul Saha and Ara (2012), who mentioned that pasteurization and sterilization processes revealed significant influence on pH, titratable acidity, specific gravity, lactose, fat protein and ash content of milk and skemmed milk.

Effect of pasteurization on micorobial load in goat milk

According to Table 4, the tpc values (×10^5 cfu/ml ) were 8.6, 7.0, 6.0, 6.0, 5.3 5.3, 4.6, 4.4, 3.6 and 12.1 as control sample respectively. The results showed significant difference (P≤ 0.05) between each sample. The values of yeast were 5.0, 4.0, 3.3, 2.3, 2.3, 2.3, 1.3, 2.0, 2.3 and 7.5 respectively. Significant difference (P≤ 0.05) between Y1, Y2, Y3, Y7, Y8, and control was seen. Moreover, no significant difference was seen between Y4, Y5, Y6 and Y9. The amount of microbials loaded in raw milk was reduced by all treatment types of pasteurization. On the other hand, 80 °C for 15 min of pasteurization reduced the amount of total plate count, yeast and mould compared to control 12.1 - 3.6, 7.5 - 2.3, 10.0 - 3.3 ×10^5 cfu/ml.
respectively. Therefore, the microbiological results highlighted that pasteurization was effective to reduce microbial loading in milk. Moreover, the pasteurizing milk at different temperature for different times such as 72, 80 and 85°C for 5, 10 and 15s were effective to decrease count of microbials in milk. These reductions are possibly enough to improve the quality of raw milk, thus increase quality of products made from it. These results are in agree with Cavalcant et al. (2013). SNI (2011) set the microbial contamination in fresh milk at a maximum limit of Enterobacteriaceae consisting $1 \times 10^5$ cfu/ml and Staphylococcus aureus of $1 \times 10^5$ cfu/L. The total plate count (TPC) has a maximum $1 \times 10^5$ cfu/ml. In addition, the pasteurization at 85°C for 15s is capable of reducing microbial load in raw milk; however, most heat fresh goat milk at higher temperature to shorten time such as 85°C to 5s or 72°C for 15s.

## Conclusion

This study concludes that temperature and time has significant ($P < 0.05$) effect on goat milk chemical composition such as lactose, protein, fat, non-fat solids contents and physicochemical properties such as pH, density, and freezing point. On the other hand, it decreases protein, fat, pH, and density, while increases the lactose and non-fat solids of goat milk. Therefore, the 85°C for 5s increased the level of non-solids and lactose in goat milk unsuitable for producing goat milk yogurt powder.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

## ACKNOWLEDGEMENT

The authors are grateful to the ministry of research, technology and higher education, and to the Research and Society Service Institute of Universitas Gendarman Soedirman for their funding and support. They also want to thank Omdurman Islamic university for the collaboration.

## REFERENCES

Almeida LAGF, Cavalcante MT, Castro RD, Cavalcanti AL (2010). Carogiogenic and erosive potential of industrialized fruit juices available in Brazil. Brazilian Journal of Oral Sciences 9(3):351-357.

Aburas H, Hassan FA, Abd El-Gawad MA, Enab A (2014). Physicochemical Characteristics of Goat’s Milk. Igars 11(11):307-17.

Abd Elrahman AMS, Ahmed MMA, El Zubeir MEI, El Owni OAO, Ahmed AKM (2013). Effect of Storage Temperature on The Microbiological and Physicochemical Properties of Pasteurized Milk, Annals. Food Science and Technology 14(1).

Aguirre B D, Mawson R, Versteeg K, Cánovas BVG (2009). Composition Properties. Physicochemical Characteristics and Shelf Life of whole Milk After Thermoand Thermo-Sonication Treatments. Journal of Food Quality 32:283-302.

AOAC (2005). Official methods of analysis. The association of official analytical chemists. 16th Edition, North Fredrick Avenue Gaithersburg, Maryland, USA.

Cavalcante DA, Leite Júnior BRC, Tribst AAL, Cristianini (2013). Improvement of the raw milk microbiological quality by ozone treatment. International Food Research Journal 20(4):2017-2021.

Chugh A, Khanal D, Walking R M, Corredig M, Duizer L, Griffiths MW (2014). Change in Color and Volatile Composition of Skim Milk Processed with Pulsed Electric Field and Microfiltration Treatments or Heat Pasteurization. Journal of Foods 3:250-368.

Contreras VIP, Gaspar MPB, Luis ALB, Victor RMM, Ana MSR (2015). Milk Composition and Its Relationship with Weaning Weight in Charolais Cattle. Revista Brasileira de Zootecnia 44(6):207-12.

El-Zubeir IEM, Gabriechise V, Johnson Q (2007). Study on some quality control measures of pasteurized milk of the Western Cape, South Africa. International Journal of Dairy Sciences (4):372-379.

Elhasan SMO, Bushara AMM, Abdelhakam KEK, Elfaki HA, Elbad AIA, Farahat FH, Ali EMY, Sukrab AMA (2017). Effect of Heat Treatments on Physico-chemical properties of Milk Samples. Journal of Academy and Industrial Research (JAIR) (6)(3).

Fraz F, Valdez GF, Pec N (2014). Effect of Pasteurization Temperature, Starter Culture, and Incubation Temperature on the Physicochemical Properties, Yield, Rheology, and Sensory Characteristics of Spreadable Goat Cheese. Journal of Food Processin 2014, Article ID 705746, 8.

Guetoouache M, Bettache G, Samir M (2014). Composition and nutritional value of raw milk. Issues in Biological Sciences and Pharmaceutical Research 2(10):115.
Guowei S, Chunju B, Chen H, Wang W, Yang H (2016). Fermentation optimization of goat milk with lactobacillus acidophilus and Bifidobacterium bifidum by box-behken design. Acta Scientiarum Polonorum. Technologia Alimentaria 15(2):151-159.

Hamodah SE, Robi A, Efrimardawati, Ibrahim AI (2018). Influence of Ozone and Pasteurization on physico-chemical properties, Microbiology, and stability of milk. International Journal of Engineering Science Invention 8(1 Series. III):2319-6726.

Igbabul B, Shember J, Amove J (2014). Physicochemical, Microbiological and Sensory Evaluation of Yoghurt Sold in Makurdi Metropolis. African Journal of Food Science and Technology 5(6):129-35.

Ibrahim AI, Rilda N, Erminawati W, Hidayah D (2019). Effect of fermentation temperature and culture concentration on microbial and physicochemical properties of cow and goat milk yogurt. IOP Conference. Series: Earth and Environment Science 406(2019) 012009.

Kumar S, Birendra K, Rajesh K, Suryamani K (2012). Featur Eatures Nutritional F Eatur Es of Goat Milk Review Eview. Indian Journal Dairy Science 65(4):266-273.

Li Y, Joyner HS, Carter BG, Drake MA (2018). Effects of fat content, pasteurization method, homogenization pressure, and storage time on the mechanical and sensory properties of bovine milk. Journal of Dairy Science 101(4):2941-2955.

Momahon D (2013). Dairy Products in Human Nutrition Dairy Products, Food And Agriculture Organization of The United Nations.E-isbn 978-92-5-107864-8.

Miao YZ (2011). Extraction of Water-Soluble Polysaccharides (WSPS) from Chinese Truffle and Its Application in Frozen Yogurt. Carbohydrate Polymers 86(2):566-573.

Mohammad EEB, El-Zubeir I EM (2011). Chemical Composition and Microbial Load of Set Yoghurt from Fresh and Recombined Milk Powder in Khartoum State, Sudan. International Journal of Dairy Science 6(3):172-180.

Mohammad H, Mazloomi SM, Eskandari MH, Amini M, Niakosvari M (2017). The Effect of Ozone on aflatoxin M1, Oxidative Stability, Carotenoid Content and the Microbial Count of Milk. Ozone: Science and Engineering 39(6):447-453.

Pedras MM, Pinho CRG, Tribat AAL, Franchi MA, Cristianini M (2012). The effect of high pressure homogenization on microorganisms in milk. International Journal of Food Research Journal 19(1):1-5.

Pereira PC (2014). Milk Nutritional Composition and Its Role in Human Health. Nutrition 30(6):619-27.

Pestana MJ, Gennari A, Monteiro WB, Lehn ND, De Souza VFC (2015). Effects of Pasteurization and Ultra-High Temperature Processes on Proximate Composition and Fatty Acid Profile in Bovine Milk. International Journal of Food Technology 10(6):265-272.

Raikos V (2010). Effect of heat treatment on milk protein functionality at emulsion interfaces. A review. Food Hydrocolloids 24:259-265.

Saha S, Ara A (2012). Chemical and Microbiological Evaluation of Pasteurized Milk Available in Sylhet City of Bangladesh. The Agriculturists 10(2):104-108.

Samaržija D, Zamberlin S, Pogačić T (2012). Psychrotrophic bacteria and milk and dairy products quality; Review. Mljekarstvo 62(2):77-95.

Sestan I, Odobašić A, Bratović A (2016). The effect of heat treatment on the physical-chemical properties of milk. Academia Journal of Environmental Science 4(7):131-136.

Saha S, Ara A (2012). Chemical and Microbiological Evaluation of Pasteurized Milk Available in Sylhet City of Bangladesh. The Agriculturists 10(2):104-108.

Slacanac V, Bozanic R, Hardi J, Rezessyne S J, Lucan M, Krstanovic V (2010). Nutritional and therapeutic value of fermented caprine milk. International Journal of Dairy Technology 63(2):171-189.

Thai Agricultural Standard TAS (2008). Raw Goat Milk. Published in the Royal Gazette Vol. 125 Section 139 D, dated 18 August B.E.2551.

Ul Hag S, Khaskheli M, Kiani FA, Talpur AR, Lochi GM, Soomro AA, Salman M, Marri MY, Mari MM (2013). Effect of Heat Treatments on Physico-Chemical Characteristics of Skimmed Milk. Journal of Agriculture and Food Technology 3(12):5-13.

Vargas M, Cháfer M, Chiralt A, González-Martínez C (2008). Physicochemical and sensory characteristics of yoghurt produced from mixtures of cows’ and goats’ milk. International Dairy Journal 18(12):1146-1152.

Wang C, Zhu Y, Wang J (2016). Comparative study on the heat stability of goat milk and cow milk. Indian Journal of Animal Research 50(4):610-613.

Wu H, Liming H, Guoping Z (2016). Effects of Electro-Osmosis on the Physical and Chemical Properties of Bentonite. Journal of Materials in Civil Engineering 28(8):0618010.

Yusa M, Ismail, Razali, Ferasyi R, Syafruddin, Panjatan B (2017). Analysis kadar lemak Analisis Kadar Lemak Susu Kambing Perankan Etawa Sebelum Dan Sesudah Dipasteurisasi Di Peternakan Lamnyong Kota Banda Aceh. JIMVET 2(1):35-40.

Zenebe T, Ahmed N, Kabela T, Kebede G (2014). Review on Medicinal and Nutritional Values of Goat Milk. Academic Journal of Nutrition 3:30-39.

Zhao QZ, Jin SW, Mou MY, Yue MJ, Cui CVL, Oszigeti J (2016). Use of ozone in the dairy industry: A review. International Journal of Dairy Technology 69:2.
Effects of processing methods on fatty acid profiles and biochemical compounds of Arabica coffee cultivars

Richard Kipkorir Koskei1*, Beatrice Mugendi1 and Patrick Muliro2

1Institute Food Bioresources Technology, Dedan Kimathi University of Technology, P. O. Box 657-10100 Nyeri, Kenya.
2Department of Dairy and Food Science and Technology, Egerton University, P. O. Box 536-20115 Njoro, Kenya.

Received 14 February, 2020; Accepted 27 April, 2020

Coffee cherries were processed traditionally by the wet method that uses large quantities of water and eco-friendly methods that utilize less water and operate mechanically to remove mucilage. The study is aimed at determining the effects of traditional and newly developed coffee processing methods on fatty acid profiles and biochemical components of two coffee cultivars. A complete randomized design was used for the study. Fresh coffee cherries for two cultivars commonly grown in Kenya, Ruiru 11 and SL 28, were processed using three different processing methods. The methods varied on the mode of mucilage removal and pulping techniques. The parchment obtained from the three processes, wet pulper, hand pulper and eco-pulper methods, were sundried and subjected to chemical analysis. Fatty acids profiles were analyzed by the use of a gas chromatography method and biochemical content; caffeine, trigonelline and chlorogenic acid were determined by HPLC analysis. The processing methods showed significant variations in the fatty acids concentrations but did not significantly affect the levels of biochemical compounds. The concentration of fatty acids ranges from 1.16 to 1.68%, with linoleic acid being dominant. The trigonelline level ranges from 1.24 to 1.36%, caffeine ranges from 1.36 to 1.45% and chlorogenic acid from 5.34 to 5.46% in the samples from the different processing methods.

Key words: Processing methods, coffee cultivars, fatty acids, biochemical compounds.

INTRODUCTION

Coffee is one of the most widely used nonalcoholic drinks and its consumption is spreading globally. It is the second most important commodity exchanged in world markets, next to crude oil (Haile and Kang, 2019a). The coffee bean is obtained from the fruit of the coffee plant, a small evergreen shrub belonging to the genus Coffea, family Rubiaceae. Kenya produces mainly Arabica coffee (Coffea arabica L.) (Kathurima et al., 2012). The old cultivars grown in Kenya are K7 for low altitude areas prone to leaf rust and the SL28 and SL34 for low to medium altitude areas with good rainfall (Mwangi, 1983). The other cultivars are Ruiru 11 and Batian which are suitable for all coffee growing areas in Kenya because of their resistance to Coffee Berry Disease (CBD) and Coffee Leaf Rust (CLR) (Opile and Agwanda, 1993; Kathurima et al., 2012). After harvesting of the fruits, green
coffee beans are obtained through processing by use of either the dry or wet methods (Murthy and Naidu, 2011) and semidried (Haile and Kang, 2019a). In the dry method, the whole cherry is dried under the sun or mechanical dryer, followed by mechanical removal of the dried outer parts (Duarte et al., 2010). The wet method requires the use of specific equipment and substantial amounts of water, in which the pulp is eliminated by a pulper, followed by natural fermentation (Gonzalez-Rios et al., 2007). Semidrying processing is a combination of both dry and wet methods, in which the coffee fruits are depulped but the fermentation process occurs directly under the sun on a platform (Vilela et al., 2010; Haile and Kang, 2019a). At the end of fermentation, the wet processed seeds are washed and dried (Duarte et al., 2010). There are different categories of coffee pulping methods which vary depending on the type of equipment and the mucilage removal processes. The pulping method may be done as continuous processing operation with the use of a mechanized disc pulping equipment or with the use of manually operated equipment. The mucilage removal could be done through natural fermentation and washing with excess water and the process called fully washed method. The other method involves a mechanical operation where the mucilage is scraped by a specialized unit of the pulping machine called an eco-pulper. The natural fermentation and washing of coffee entails the traditional method of removing mucilage while the mechanized process is a new technology considered to be economical and fast in its processing of coffee berries (Roa et al., 2019).

Variations in the quality of coffee obtained by the use of the different processing methods have been reported in literature (Gonzalez-Rios et al., 2007; Bytof et al., 2005; Haile and Kang, 2019a). However, there is scanty information on the effects of different processing methods on the chemical components such as fatty acids and other biochemical compounds. The lipid content in coffee grounds ranges from 10 to 17%. However, compared to Coffea canephora, higher lipid contents are found in Arabica coffees (Figueiredo et al., 2015). For most of the lipids, the coffee oil, are located in the endosperm of green coffee beans and a small amount, the coffee wax, is located on the outer layer of the bean. The coffee oil fraction is mainly composed of triacylglycerols, which have fatty acid proportions similar to those found in edible vegetable oils (Speer and Kölling-Speer, 2006). Triacylglycerols are the major carriers of aroma in the roasted bean. Their fatty acid composition determines the generation of thermally-induced oxidation products, in particular aldehydes, which react readily with Maillard intermediates, giving rise to additional aroma compounds. Biochemical compounds in coffee such as chlorogenic acid and caffeine are responsible for bitterness (Joet et al., 2010). Trigonelline is a pyridine derivative known to contribute indirectly to the formation of appreciated flavor products including furans, pyrazine, alkyl-pyridines and pyrroles during coffee roasting (Ky et al., 2001; Perrone et al., 2008). Therefore, coffee processing methods influence on the levels of these components may affect the quality characteristics of roasted coffee beans. There may be variations also in the levels of chemical components among different coffee cultivars such as Ruiru 11 and SL 28. Hence there is need to determine the levels of fatty acids and biochemical components in this cultivars which are among the major determinants of coffee quality. This research aimed at determining the effects of different processing methods on the concentrations of fatty acids and biochemical components in two coffee cultivars commonly grown in Kenya.

MATERIALS AND METHODS

Preparation of coffee samples

The red ripe coffee cherries were harvested and processed by three processing methods classified as wet pulper, hand pulper and eco-pulper methods. Wet pulper method was done by continuous pulping operation. The parchments were fermented in plastic containers by dry fermentation for 18 h. It was then washed and graded and the heavier grade (P1) dried and used for analysis. Hand pulper method was done by use of a motorized manual pulping machine. The parchments were subjected to fermentation in plastic containers with dry method for 18 h. After fermentation the parchment were washed and graded and heavier grade dried and used for analysis. The eco-pulper method was done by use of ecological pulping equipment. The machine removed mucilage and cleaned the parchment with little water without fermentation of the coffee parchment. The coffee parchments from the three methods were dried in the sun to a moisture content of 10 ± 1%. The dry parchments were then packed and sealed in polythene bags and stored in a freezer at -18°C until time for analysis.

Analysis of fatty acids

Lipids were extracted according to the method of Bligh and Dye (1959). The fatty acids in coffee samples were converted to Fatty Acid Methyl Esters (FAME) according to the method described by Ogara (2013). Fatty acid profile analysis was done using gas chromatograph (Shimadzu GC-9A) fitted with capillary column (15%, Diethylene glycol-succinate) and flame ionization detector temperature of 220°C and injector temperature of 170°C. Nitrogen was used as carrier gas. Fatty acid methyl esters were identified by comparison of retention times of the samples with standards and their concentrations expressed as mg/100 g dw.

Determination of Biochemical compounds

The analysis of chlorogenic acid, caffeine and trigonelline were done according to the method by Ky et al. (2001) and described by Gichimu et al. (2014). The HPLC equipment (Knauer, Japan) was used with a column (YMC_ Pack polyamine __, 250× 4.6 mm, I.D.S_5 μm, 12 nm) and detector (knauer K2600A UV). The mobile phase used was acetonitrile (40%) and formic acid (5%) and the pumps operated in isocratic mode with solvent flow of A (37%) and B (63%). The flow rate was set at 1 ml/min. The peaks were
Effects of processing methods on the fatty acid concentrations of green coffee

The green coffee beans samples for two main cultivars namely SL 28 and Ruiru 11 were used in the analysis. The results for the fatty acid concentrations are presented on Tables 1 and 2. A sample chromatograph for fatty acids profiles is shown on Figure 1. The samples were processed using three different pulping methods. The fatty acids detected include: palmitic, stearic, oleic, linoleic and linolenic acids. Linoleic acid showed the highest concentration with a range of 13-19 mg/100 g, followed by palmitic (7-10 mg/100 g), stearic (2-5 mg/100 g), oleic (2-4 mg/100 g) and linolenic acid (1-4 mg/100 g) for green coffee samples analysed. Similar trends in the concentration of fatty acids have also been reported by other authors (Martin et al., 2001; Figueiredo et al., 2015; Hung et al., 2018). The coffee samples were processed by three pulping methods named as wet pulper, hand pulper and eco-pulper methods. The pulping methods varied in terms of whether the method involved fermentation process or not and the level of water used during processing. The results indicate that there were significant differences (p<0.05) between the processing methods on the concentrations of some fatty acids content especially for the SL 28 samples. For Ruiru 11 samples, there were no significant variations between the processing methods on the levels of the fatty acids contents.

The hand pulper method showed slightly lower significant levels for some fatty acids content such as palmitic acid, stearic acid, oleic acid and linoleic acid. This variation in the levels of fatty acids could be attributed to the differences in the processing conditions. The eco pulper method which operates without fermentation showed slightly higher trends for the fatty acids contents compared to the wet and hand pulper methods which use fermentation and excess water during processing. Haile and Kang (2019a) indicated reduction of lipids content after fermentation of mucilage. The low levels of fatty acids in the wet and hand pulper methods
could be attributed to loss of materials from the coffee due to fermentation and washing processes. Joet et al., (2010) reported occurrence of metabolic processes during wet processing of coffee affecting their chemical composition. In this study it is suggested that the methods with fermentation could expose the coffee beans to microbial and enzymatic activities which may influence the degradation of chemical components. The chemical components in the coffee beans may then be reduced or loss due to processing. Variations in the levels of chemical composition due to the influence of metabolic activities in coffee beans have also been reported by other authors such as Selmar et al. (2006) and Patui et al. (2014). The lipase activity has been reported to be present in the coffee seed which can catalyze the hydrolysis of ester bonds in monoacylglycerol, diacylglycerol and triacylglycerols into free fatty acids and glycerol (Toci et al., 2013; Patui et al., 2014). It is reported that majority of lipids are found in the oil fraction of the coffee bean endosperm and a small amount, the coffee wax, is located on the outer layer of the bean. Hence those on the outer layers may be affected by processing or metabolic activities. The coffee oil fraction is mainly composed of triacylglycerols, which have fatty acid proportions similar to those found in edible vegetable oils (Speer and Kölling-Speer, 2006; Figueiredo et al., 2015).

Effects of processing methods on biochemical content of coffee.

Caffeine, trigonelline and chlorogenic acid are the common biochemical components of coffee. Table 3 shows the results of the effects of processing methods on these components in coffee samples processed by the three processing methods. Trigonelline in the SL 28 samples range from 1.24 to 1.29% while in Ruiru 11 the range was between 1.28 to 1.36%. Processing methods did not show any significant differences (p<0.05) on the levels of trigonelline for the coffee samples analysed. The levels for caffeine in SL 28 ranged from 1.26 to 1.36% and 1.29 to 1.45% in the Ruiru 11 samples. The processing methods did not show significant variation on the caffeine content for both the SL 28 and Ruiru 11 samples. The chlorogenic acid content in the SL 28 samples ranged from 5.34 to 5.44% and 5.36 to 5.46% for Ruiru 11 samples. The level of trigonelline, caffeine
and chlorogenic acid in the coffee samples were within the levels reported by other authors (Mussatto et al., 2011; Gichimu et al., 2014). Though the compounds such as trigonelline and chlorogenic acid are reported as water soluble components which could be loss by squeezing of coffee (Nigam and Singh, 2014), the wet pulper and hand pulper methods which use fermentation did not show any significant reduction for the tested compounds. This could be because the compound are strongly bound within the endosperm of coffee beans and cannot easily be lost through washing and squeezing of coffee parchment during mucilage removal. Similarly the compounds could not be affected by fermentation process.

However Haile and Kang (2019b) reported an increase of total polyphenol content of green coffee beans after fermentation with different strains of yeast. Other authors reported no changes on the level of these compounds due to different processing methods. Duarte et al. (2010) did not find any significant variations on the level of caffeine between wet processing and semi dry processing methods. Ferreira et al. (2013) studied the effects of wet and dry processing of coffee on chemical composition and did not find any significant variations on the levels of caffeine. However, Nigam and Singh (2014) reported loss of chlorogenic acid from coffee during wet processing due to the effect of leaching into the processing water. The eco-pulper using less water compared to the wet and hand pulper methods did not show significant variations between these methods on the level of chlorogenic acid. The level of chlorogenic acid was within the levels reported in the literature. Farah et al. (2006) reported a range of 4 to 14% in green coffee beans. The stability of these biochemical compounds during processing of coffee is important for determination of the quality of coffee beverage. These compounds are important in influencing the aroma and flavor of coffee. The thermal degradation of chlorogenic acids during roasting results in formation of phenolic substances that contribute to bitterness and aromatic compounds which are undesirable to cup quality (Toci and Farah, 2008). Trigonelline is a pyridine derivative known to contribute indirectly to the formation of appreciated flavor products including furans, pyrazine, alkyl-pyridines and pyroles during coffee roasting (Ky et al., 2001). Caffeine with its characteristic bitter taste is an important determinant of coffee flavor (Farah et al., 2006).

### Conclusion

From the study, it can be deduced that the processing methods showed variations on the level of some fatty acid components of coffee. SL 28 samples showed more significant variations than the Ruiru 11 samples. The methods with fermentation process displayed less fatty acid levels than the method without fermentation process. The processing methods that use excess water and fermentation process did not vary from the methods with little water and no fermentation in regard to the levels of biochemical compounds. SL 28 cultivar showed slightly higher concentration of fatty acids than the Ruiru 11 cultivar. There was no significant variation in the level of biochemical compounds for both cultivars when processed by different methods.

### CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

### ACKNOWLEDGEMENT

The authors appreciate the National Research Fund (NRF), formerly the National Council of Science and Technology (NACOSTI), for the sponsorship. The authors also appreciate the services of the technical staff of Coffee Research Institute and Jomo Kenyatta University of Agriculture and technology.

### REFERENCES

Bligh E, Dye WJ (1959). A rapid method of total lipid extraction and purification. Journal of Canadian Biochemistry 37:911-917.
Bytof G, Knopp SE, Schieberle P, Teutsch I, Selmar D (2005). Influence of processing on the generation of γ-aminobutyric acid in green coffee beans. European Food Research Technology 220(3-4): 245–260.

Duarte GS, Pereira AA, Farah A (2010). Chlorogenic acids and other relevant compounds in Brazilian coffees processed by semi-dry and wet post-harvesting methods. Journal of Food Chemistry 118:851–855.

Farah A, Monteiro MC, Calado V, Franca AS, Trugo LC (2006). Correlation between cup quality and chemical attributes of Brazilian coffee. Journal of Food Chemistry 98:373.

Ferreira GF, Novaes QS, Malta MR, Souza SE (2013). Quality of coffee produced in the SouthWest Region of Bahia, Brazil subjected to different forms of processing and drying. African Journal of Agricultural Research 8(20):2334-2339.

Figueiredo LP, Borém FM, Ribeiro FC, Giomo GS, Taveira JSS, Marcelo R, Malta MR (2015). Fatty acid profiles and parameters of quality of specialty coffees produced in different Brazilian regions. African Journal of Agricultural Research 10(35):3484-3493.

Gichimu JM, Murungi EK, Mambilé GE, Nyende AB (2014). Biochemical Composition within Coffea arabica cv. Ruiri 11 and Its Relationship with cup quality. Journal of Food Research 3(3):31-44.

Gonzalez-Rios O, Suarez-Quiroz ML, Boulanger R, Barel M, Guoyt B, Guiraud J-P, Schorr-Galindo S (2007). Impact of “ecological” post-harvest processing on coffee aroma: II. Roasted coffee. Journal of Food Composition Analysis 20:297–307.

Haile M, Kang WH (2018a). The Role of Microbes in Coffee Fermentation and Their Impact on Coffee Quality. Journal of Food Quality, Article ID 4836709, 6 https://doi.org/10.1155/2019/4836709

Haile M, Kang WH (2018b). Antioxidant Activity, Total Polyphenol, Flavonoid and Tannin Contents of Fermented Green Coffee Beans with Selected Yeasts. Fermentation 5:29.

Hung Y-C, Chen P, Chen L-Y (2018). Advanced Classification of Coffee Beans with Fatty Acids Profiling to Block Information Loss. Symmetry 10:529.

Joel T, Lafargue A, Descroix F, Douibeau S, Bertrand B, de Kochko A, Dussert S (2010). Influence of environmental factors, wet processing and their interactions on the biochemical composition of green Arabica coffee beans. Journal of Food Research 118:693-701.

Kathurima C, Kenji G, Muhoho S., Boulanger R, Ng’ang’a F (2012). Volatile Organic Compounds in Brewed Kenyan Arabica Coffee Grains as determined by Solid Phase Extraction Gas Chromatography Mass Spectrometry. Journal of Food Science and Quality Management (8):18-26.

Ky CL, Dussert S, Guyot B, Hamon S, Noirot M (2001). Caffeine, trigonelline, chlorogenic acids and sucrose diversity in wild Coffea arabica L. and C. canephora P. accessions. Journal of Food Chemistry 75:223–230.

Martin MJ, Pablos F, Gonzales AG, Valdenebro MS, Leon-Camacho M (2001). Fatty acid profiles as discriminating parameters for coffee varieties differentiation. Talanta 54 (2):291–297.

Murphy PS, Naidu MM (2011). Improvement of Robusta coffee fermentation with Microbial Enzymes. European Journal of Applied Science 3(4):130-139.

Mussatto SI, Machado EMS, Martins S, Teixeira JA (2011). Production Composition and Application of Coffee and its Industrial; Residues. Food Bioprocess Technology 4:661-672.

Mwangi CN (1983). Coffee Growers’ Handbook. Coffee Research Foundation, Kenya, 128 pp.

Nigam PS, Singh A (2014). Cocoa and coffee fermentations. Encyclopedia of Food Microbiology (Second edition), pp. 485-492.

Ogara RS (2013). Evaluation of nutritional properties of yellow oleander (Thevetia Peruviana) Seeds in Kenya. Food Science and Quality Management, ISSN 2224-6088 (Paper) ISSN 2225-0557 (Online) Vol. 22.
Full Length Research Paper

Sensory evaluation of four pepper soup dishes prepared with four varieties of protein sources using Itsekiri pepper soup spices

Keswet Larai A.¹ and Abia Florence O.²

¹Department of Science and Technology Education, University of Jos, Plateau State, Nigeria.
²Department of Home Science and Management, Federal University of Agriculture, Makurdi, Benue State, Nigeria.

Received 21 November, 2019; Accepted 4 March, 2020

Four types of protein sources were used in the preparation of pepper soup dishes using Itsekiri pepper soup spices were evaluated. The protein sources used for the pepper soup dishes were: Cow-leg, goat meat, fresh fish and dry stock fish. Sensory evaluation of the four pepper soup dishes was done using 40 trained panelists based on a 5-point hedonic scale. Result on the acceptability of the soup dishes revealed that dry stock fish pepper with 4.58±0.50 was highly acceptable, cow leg pepper with average score of 3.93±0.80 was moderately acceptable, fresh fish pepper soup with 3.85±0.86 was also averagely acceptable while goat meat pepper soup with score of 3.48±0.64 was the least acceptable. Based on the results of the ratings of the dishes, it was recommended that the pepper soup seasoning was generally acceptable and hence, should be promoted on a wider level.

Key words: Pepper soup, Itsekiri spices, protein sources, sensory evaluation, acceptability.

INTRODUCTION

A soup is a liquid food prepared by boiling fish, meat or vegetable stock as a base. Soups generally accompanied main meals to rouse appetite for food. According to Tapsell et al. (2006) and Jiang (2019) seasonings, which are also ingredients used in soup making are composed of notable list of phyto-nutrients, essential oils, antioxidants, minerals and vitamins that are essential for good health. It is interesting however to note that the use of seasonings in food preparation has been an old tradition for many cultures of the world. The use of seasonings in food preparation has also become an integral part of life over the centuries, in many parts of the world (Tapsell et al., 2006; Otunola et al., 2010).

Seasonings are ingredients which are added to foods to enhance flavor. These ingredients included salt, onion, curry, parsley, sesame seeds, mint and thyme; pepper powder and condiments such as mustard and vinegar. Apart from adding flavour to foods, some seasonings also contained medical and health benefits such as lowering of cholesterol levels, removal of scalp itching and peeling caused by candidiasis, relieve arthritis and back pain, healing of colds, sinus infections and sore throats, burn

*Corresponding author. E-mail: lakeswet@yahoo.com.

Author(s) agree that this article remain permanently open access under the terms of the Creative Commons Attribution License 4.0 International License.
calories, speed up metabolism, cancer-fighting and anti-inflammatory properties, help to fight communicable diseases as well as lower the levels of bad cholesterol and triglycerides in the blood (Ajayi et al., 2013; Jiang, 2019).

In Nigeria, seasonings are commonly used in the production of dishes and drinks such as: pepper soup, jollof rice, yam porridge, all types of soups and stews, local drinks such as Zobo, ginger and other fruit drinks. Though, seasonings are used in small quantities that they contribute to the nutrient content of the food (Jiang, 2019). These seasonings are manufactured as bouillon cubes and in powdered form which are packaged with different brand names and are used extensively in food preparation (Otunola et al., 2010; Ajayi et al., 2013). They are added to soups, stews, puddings and sometimes as stimulants which are mixed along with other beverages and used as pepper soup ingredients.

The Nigerian, pepper soup is a popular soup recipe. It is usually prepared with different types of protein sources such as chicken, beef, goat meat, cow leg, other assorted types of meat, animal intestines, fresh or dried fish (Keswet and Abia, 2015). People usually eat pepper soups at home, exclusive hotels, bars and beer parlors. Also, pepper soup dishes are eaten by both male and female, in all parts of Nigeria. Different cultures prepare pepper soup dishes in different ways, with different ingredients/spice and for different purposes (Keswet and Abia, 2015). Among the Itsekiri tribe in Nigeria, some seasonings are especially used to prepare special pepper soup for women who have just delivered. It is believed that the use of these soups helps to quicken the healing of the body processes after birth. The ingredients used in the preparation of Itsekiri pepper soup seasonings included: *Monodora myristica* (Iwo), *Tetrapleura tetraptera* (Iyanghangangh), *Panirari curatellifolia* (Aghafilo), *Chrysobalanus icaco* and *Xylopia ethiopica*. In northern Nigeria, just like in Itsekiri land, various seasonings are used for the preparation of pepper soup dishes, local puddings, gruels, local food drinks and various snacks (Keswet and Abia, 2015). Such seasonings are produced locally by many households and are also added to the nursing mother’s foods and drinks.

The aim of this study was to prepare four pepper soup samples using Itsekiri pepper seasoning as well as using goat meat, cow leg, fresh fish and dried stock fish as sources of protein. This was done to assess the general acceptability of the pepper soup dishes.

### MATERIALS AND METHODS

The following spices: (1) *M. myristica* (Iwo), (2) *T. tetraptera* (Iyanghangangh), (3) *P. curatellifolia* (Aghafilo), (4) *C. icaco* and (5) *X. ethiopica* were bought from Terminus market in Jos, Plateau State, Nigeria. The spices were cleaned, mixed together, ground and sieved into fine pepper soup powder using a standard (fine) kitchen sieve. Salt was also added to taste (pepper soup seasoning). The seasoning was packaged into 100 g samples.

The following ingredients: 1 kg each of cow leg, goat meat, fresh fish and dry stock fish were bought from Terminus market. Other ingredients included 8 sachets of 100 g Itsekiri seasoning, 4 Knorr cubes and salt to taste. These ingredients were divided into four portions and each portion was added to the following protein sources to prepare four pepper soup samples: (A) cow leg, (B) goat meat, (C) fresh fish and (D) dry stock fish respectively. Keswet and Abia (2015), pepper soup recipe was adopted as control for the production of the four samples as follows: Wash the stock fish, rinse thoroughly and cut into smaller pieces. Place in a pot, add enough water to cover the stock fish, add the Itsekiri pepper soup seasoning and cook until the stock fish is done cooking.

Panelists were composed of 40 men and women (middle aged and income earners) purposively selected by simple random sampling technique for the sensory evaluation. There was an equal selection of 20 males and 20 females for the study. Each panelist was offered small portions of the pepper soup samples in small white soup plates which were coded cow leg pepper soup (CLP), goat pepper soup (GPS), fresh fish pepper soup (FFP) and dry stock fish pepper soup (DSP), based on a five hedonic scale (1 and 5, representing extreme like and extreme dislike respectively), of taste, aroma, appearance, visual texture and general acceptability. Only one sensory attribute was tested in one sitting and in separate compartments with good lighting. Data collected were subjected to analysis of variance (using IBM SPSS version 20) at 0.05 level of significance.

### RESULTS

Table 1 presented the analysis of data, using means and standard deviation (mean ± SD) on the acceptability level of Itsekiri pepper soup. Samples A - C are the experimental while sample D is the control. Table 1 showed that the acceptability of pepper soup dishes

| Sample code | Source of protein | Aroma  | Appearance | GA  | Sensory attribute | Overall acceptability |
|-------------|------------------|--------|------------|-----|-------------------|----------------------|
| A           | CLP              | 3.93±0.73 | 3.15±0.95 | 3.93±0.80 | 3.30±0.82 | 4.05±0.597 | 3.67 |
| B           | GPS              | 3.40±0.55 | 2.88±0.56 | 3.46±0.64 | 3.10±0.59 | 3.58±0.64 | 2.57 |
| C           | FFP              | 3.78±0.66 | 3.58±0.78 | 3.85±0.86 | 3.25±0.54 | 3.83±0.81 | 3.66 |
| D           | DSP              | 3.93±0.53 | 4.05±0.71 | 4.58±0.50 | 3.78±0.66 | 4.45±0.68 | 4.16 |

GA: General acceptability.
Table 2. Comparative analysis of pepper soup samples by gender.

| Attributes         | Gender | N  | Mean | Std. deviation | Df  | t_cal | P-value |
|--------------------|--------|----|------|----------------|-----|-------|---------|
| Taste              | Male   | 20 | 4.15 | 0.49          | 38  | 1.061 | 0.298   |
|                    | Female | 20 | 3.95 | 0.69          |     |       |         |
| Aroma              | Male   | 20 | 3.65 | 0.59          | 38  | -2.545| 0.015   |
|                    | Female | 20 | 4.20 | 0.77          |     |       |         |
| Appearance         | Male   | 20 | 2.90 | 0.79          | 38  | -1.707| 0.096   |
|                    | Female | 20 | 3.40 | 1.05          |     |       |         |
| General acceptability | Male | 20 | 3.85 | 0.75          | 38  | -0.590| 0.559   |
|                    | Female | 20 | 4.00 | 0.86          |     |       |         |
| Visual texture     | Male   | 20 | 3.10 | 0.72          | 38  | -1.566| 0.126   |
|                    | Female | 20 | 3.50 | 0.89          |     |       |         |

based on protein sources with score sheets (Smiley’s) on a 5-point hedonic scale of “poor” to “excellent”, and dishes ranked to determine consumer preference. The dishes showed significant levels of acceptability across the various sources of protein. Based on aroma in Table 1, CLP and DSP dishes were moderately acceptable (3.93±0.73), followed by FFP (3.78±0.66) and the least aroma score was GPS (3.40±0.55). Appearance scores of the dishes revealed that DSP with 4.05±0.71 was highly acceptable followed by FFP with 3.58±0.78 as moderately acceptable, CLP with 3.15±0.95 was averagely acceptable and GSP with 2.88±0.56 was the least acceptable.

General acceptability of the dishes revealed that sample D (stock fish, DSP) with 4.58±0.50 was highly acceptable followed by sample A (cow leg, CLP) with average score of 3.93±0.80 was moderately acceptable, sample C (fresh fish, FFP) with 3.85±0.86 was averagely acceptable and sample B (goat meat, GPS) with score of 3.48±0.64 was the least acceptable. The study revealed that DSP had the highest score overall acceptability (4.15), while GPS had the lowest (3.24).

Table 2 showed the t-Test analysis of pepper soup samples based on gender. Parameters used for rating were: taste, aroma, appearance, general acceptability and visual texture. Based on the taste assessment of the pepper soup samples, the mean score of 4.15±0.49 was very good, while the female had a mean score of 3.95±0.69 was very good with calculated t-Test value of 1.06 and p-value ≥ 0.05. This implies that there was no significant difference between male and female assessment based on taste of the pepper soup, appearance, general acceptability and visual texture. But there was a significant difference between male and female in Aroma assessment of the pepper soups with females mean score of 4.20±0.77 greater than males of 3.65±0.59. This implies that females could be more sensitive to aroma than males.

DISCUSSION

The consumption of pepper soup has become an integral part of life over the centuries in many parts of Africa and particularly in Nigeria. In Plateau State, pepper soup consumption occurred more during afternoon break periods in specific spots. Some of the spots included bars, hotels, canteens and special huts where people gather to eat and drink (Keswet and Abia, 2015). The consumption of hot pepper soup is very common among men and women who consumed alcoholic drinks such as beer and the local drink called “Burkutu”. This study is in line with that of Keswet and Abia (2015) who commented that pepper soup dishes are loved by Nigerians because of their medicinal and healing effects. According to Keswet and Abia (2015), all Itsekiri women are lovers of spices and therefore prepared them in different forms, using different types of ingredients. It was traditionally prepared for mothers who have just delivered and for convalescents. This study, along with others have confirmed the wide acceptance and use of various pepper soups dishes prepared from various seasonings and using meat varieties such as bush meat, poultry and both dry and fresh fish (Keswet and Abia, 2015; Salmon, 2016).

Pepper soup dishes are widely accepted because of their health and nutritional benefits. Thus, the results revealed that pepper soup dishes prepared from Itsekiri pepper soup seasonings were highly acceptable. Table 1 showed that all the pepper soup samples were generally
accepted at different levels by the respondents. This confirms the assertion that pepper soup in Nigeria has become such a general dish across all cultures (Salmon, 2016). It is a delicacy dish for many cultural groups which goes with palm wines, local wines (Burkutu and Pito) and other alcoholic beverages. According to Keswet and Abia (2015), Nigerian pepper soup is such a versatile recipe as it can be prepared with different types of meat and fish such as cow leg, cow tail, chicken and catfish, among many others.

The results of the sensory analysis have shown the wide acceptance of Itsekiri pepper soup dishes prepared with four different protein sources and consumed by both males and females. Ajayi et al. (2013) have also shown that many of the local seasonings are beneficial and very good sources of minerals which help the metabolic processes inside the body cells. The existence of these nutrients in the pepper soup seasoning as well as in the type of protein used and other ingredients used, can help to meet some of the nutritional requirements of individuals (Bouba et al., 2012; Keswet and Abia, 2015; Jiang, 2019). Based on the results of the study, the Itsekiri pepper soup dishes could be introduced successfully to all parts of Nigeria and other African countries.

Conclusion

The Itsekiri seasoning is a widely accepted condiment in the preparation of some kinds of pepper soup dishes. It can also be used like other popular seasonings like Maggi and Knorr cubes, among many others for the preparation of most Nigerian meals or menus.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Ajayi OB, Akomolafe SF, Akinyemi FT (2013). Food value of two varieties of ginger commonly consumed in Nigeria. ISRN Nutrition. ArticleID359727.5 p.

Bouba AA, Njintang NY, Foyet HS, Scher J, Montet D, Mbofung CMF (2012). Proximate composition, mineral and vitamin content of some wild plants used as spices in Cameroon. Food and Nutrition Sciences (3):423-432.

Jiang TA (2019). Health benefits of culinary herbs and spices. Journal of AOAC International, 102(2), 395-411.

Keswet LA, Abia FO (2015). Production and nutritional analysis of Itsekiri pepper soup spices. International Journal of Development Research 5(87);4905-4907.

Otunola GA, Oloyede OB, Oladji AT, Afolayan AJ (2010). Comparative analysis of the chemical composition of three Spices-Allium sativum, L. Zingiber officinalis and Capsicum frutescens L commonly consumed in Nigeria. African Journal of Biotechnology 9(41):6927-6931.

Salmon T (2016). Immaculate Bites. https://www.africanbites.com/?s=pepper+soup.

Tapsell LC, Hemphill I, Cobiac L, Patch CS, Sullivan DR, Fenech M, Roedenrns S, Keoghb JB, Clifton PM, Williams PG, Fazio VA, Inge KE (2006). Health benefits of herbs and spices: the past, the present, the future. Medical Journal of Australia 185(S4):S1-S2.
Full Length Research Paper

Effect of different processing conditions on the quality of canned sweet corn kernels produced and processed in Senegal

Nafissatou DIOP NDIAYE1*, Adjaratou BASSE DIENG2 and Thomas L. THOMPSON3

1Department of Fruits and Vegetables Processing, Institute of Food Technology, Route des PèresMaristes, B.P. 2765, Dakar - Hann, Sénégal.
2Laboratory of Food Microbiology, Institute of Food Technology, Route des PèresMaristes, B.P. 2765, Dakar - Hann, Sénégal.
3Virginia Technical College of Agriculture and Life Sciences, United States.

In Senegal, sweet corn is produced for export market while the canned ones are imported to supply national market. This work was carried out to investigate the effect of different processing conditions such as heating temperature and sterilization time on the microbial quality, color, ascorbic acid and shelf life of canned sweet corn produced in Senegal. The hygiene level of sweet corn samples at different preliminary processing stages before canning processing was evaluated also. Aerobic mesophilic total counts were lowest at blanching (1.8 log_{10} CFU/g) and no microorganisms related to food spoilage and public health concerns were detected in all canned sweet corn regardless of treatment. However, treatment E (125°C/12 min) had the highest F-value (35.7 min) and the lowest C-value/F-value ratio (3.84 min). This treatment had also less impact on total color change (ΔE*=6.81) and ascorbic acid content. Canned sweet corn was shelf stable after 12 months of storage.

Key words: Sweet corn processing, canning processing, sterilization, thermal treatment, microbial quality, shelf life, color, vitamin C.

INTRODUCTION

Sweet corn (Zea mays L. sppsaccharata), a crop that is planted worldwide, is one of the most common vegetables grown and consumed throughout the world (Siddiq and Pascall, 2011; Yu et al., 2016). According to More et al. (2018), it is a cultivated plant for human consumption and is a raw or processed material of the food industry throughout the world. For example, in the U.S. and Canada, sweet corn is considered to be a symbol of summer, being one of the most popular vegetables (Pacurar et al., 2019). Sweet corn is present in the market in fresh, frozen and canned forms (Alan et al., 2014). Recently introduced in Senegal (since 2004), sweet corn was identified by the Senegalese Government as a high value-added crop with potential for export markets (Sow and Lagnane, 2011). Production is increasing (up to 12,253 metrics tons in 2015), and more
than 40 million ears of fresh sweet corn were sold each year by one of the big five Senegalese producers (SCL, 2019). However, the country still imports canned sweet corn to cover the national market while local sweet corn production is exported fresh to European Union markets (Ndiaye et al., 2017). According to FAOSTATS (2019), 417 tons of prepared or preserved sweet corn were imported into Senegal during 2015. Thus, the production of canned sweet corn could be an opportunity to create added value and new markets for the horticulture subsector and promote the development of local food processing industry at different scale. Therefore, canned sweet corn could be a new food product made in Senegal. Furthermore, development of such processing units could contribute to reducing importations and post-harvest losses. It could be also an opportunity to diversify their market.

Because of low acidity, sweet corn is susceptible to growth of spoilage and pathogenic organisms including Clostridium botulinum, mesophilic spore-forming bacteria and thermal tolerant bacteria (Liato et al., 2016; Mishra and Sinha, 2018). In the food industry, thermal processing is one of the oldest food processing technologies and the most common process to enable microbiologically safe food and extending the useful shelf life of foods (Simpson and Abakarov, 2009; Pankaj, 2016; Mishra and Sinha, 2018). Sterilization must take into account the microbiological characteristics of the product and the storage requirements after processing. Canning is the general term applied to packaging a food in a hermetically sealed container that avoid the passage of gas or microorganisms and subjecting it to a thermal process for the purpose of extending its useful life (Berry and Pflug, 2003; Erkmen and Bozoglu, 2016). Thermal treatment may also affect quality characteristics of the final product, such as color or vitamin C content. Therefore, the purpose of this work was to investigate the effect of different heat sterilization treatments on microbial quality, color, vitamin C and shelf life of canned sweet corn produced in Senegal. The most suitable processing conditions are proposed such as heating temperature and time, with the hope that results would guide future canned sweet corn Senegalese processors to produce a safe and good quality of shelf stable canned sweet corn.

MATERIALS AND METHODS

Fresh yellow sweet corn ears (super sweet varieties) were purchased from a local sweet corn grower in Saint Louis (northern region in Senegal).

Preliminary operation stages prior to canning processing

In this study, preliminary processing stages before canning were as follows: husking, blanching, cooling, cutting and washing. Three batches of one hundred fresh sweet corn ears per batch were used for sample preparation. For each batch, ears were husked and silks were removed manually. No water was used on whole sweet corn ears before husking to prevent contamination of kernels. Furthermore, two operators carried out husking so that there was no contact between sweet corn leaves and kernels. Ears were then steam blanched for 6 min. Blanched ears were cooled in fresh water for 3 min and drained. Fresh water was used because sterile water was not available in our laboratory. After cooling, kernels were cut from the cobs, washed and drained. The colony forming units CFU/g of total aerobic mesophilic counts at 30°C were determined at different preliminary processing stages according to NF EN ISO 4833-1 (2013) to assess hygiene level of sweet corn samples.

Preparation of canned sweet corn kernels

Five batches (one batch for one combination of heating temperature and holding time) of canned sweet corn kernels are processed. For each batch, 100 fresh sweet corn ears were used to prepare canned sweet corn kernels. The unit operations were as follows: husking, cutting kernels from the cobs, washing, blanching (by steam exposure for 6 min), cooling, filling/weighting (230 g of prepared sweet corn kernels), exhausting (180 mL of hot water at 10°brix and 1% salt) and seaming (at atmospheric pressure using a semi-automatic seaming machine Sertinox S.C.I.M., Casteljoux, France). Easy open cans ref ½ haute T40 (73 mm x 109 mm) were used in this study.

Thermal sterilization of canned sweet corn kernels

After seaming, canned sweet corn kernels were sterilized to achieve microbial safety. Sterilization of canned sweet corn kernels was carried out using a vertical non-rotary retort (Techna FT 60/95E) consisting of a cylindrical storage vessel, a feeding and cooling water system, a digital thermo regulator, a temperature recording and control elements. The sterilization of sweet corn kernels was performed at the following five combinations of heating temperature and holding time: 121.1°C for 4 min (treatment A), 118°C for 40 min (treatment B), 121.5°C for 18 min (treatment C), 125°C for 8 min (treatment D) and 125°C for 12 min (treatment E). Each combination of temperature and time was tested in duplicate. A temperature data logger SL53T (0°C to +125°C ± 0.12°C accuracy) was inserted at the center point of the can for core temperature measurements. Data were analyzed with the Tempit software (Signatrol). To reduce length of cooling-up time, hot water (> 53°C) was used to fill the retort. The initial temperature of the product was also up to 50°C. Sterilization values (F-values) were calculated at each temperature by Equation 1 using a reference temperature of 121.1°C.

\[
F = \int_0^t 10^{-\frac{121.1}{Z}} dt
\]  

(1)

Where \(t\) represents time (min), \(Z\) is the temperature sensitivity of the target microorganism (for Clostridium botulinum, \(Z=10\, ^\circ\, C\)), and \(T\) represents the temperature at any given time at the center of the cans. Cook values \(C\)-values at each temperature were also calculated by Equation 2 using a temperature reference of 100°C and a \(Z\) factor of 36°C for corn (Hallström et al., 1988).

\[
C = \int_0^t 10^{-\frac{100}{Z}} dt
\]  

(2)

Microbiological quality of fresh and canned sweet corn kernels

Classical AFNOR methods of analysis are used to assess
Table 1. The presence of aerobic mesophilic total count (Log$_{10}$ CFU/g) in sweet corn samples collected after different processing stages before canning.

| Processing stage | Husking | Blanching | Cooling | Cutting | Washing |
|------------------|---------|-----------|---------|---------|---------|
| Aerobic mesophilic total counts (Log$_{10}$ CFU/g) | 5.4$\pm$ 0.3 | 1.8$\pm$ 0.6 | 3.8$\pm$ 0.7 | 4.0$\pm$ 0.7 | 3.4$\pm$ 1 |

Means values ± standard deviation of three processing batches. Different letters, denote significant differences (SNK, test).

microbiological quality of samples. The following on batches of sweet corn kernels are measured before and after each sterilization treatments: Total Aerobic Mesophilic Counts at 30°C (NF NI ISO 4833-1; 2013), thermo tolerant Coliforms (NF V08-060; 2009), Yeasts and Molds (NF V08-059; 2002), Salmonella (NF EN ISO 6579; 2002), Enterobacteriaceae at 37°C (NF ISO 21528-2; 2004), Bacillus cereus (NF EN ISO 7932; 2005a), thermophilic Bacillus (NF V08-602; 2011), mesophilic Bacillus (NF V08-602; 2011), Clostridium botulinum (NF EN ISO 7937; 2005b), sulfide-reducing spores of Clostridium (NF ISO 15213; 2003), pathogenic Staphylococci (ISO 6888-1; 1999) and fecal Streptococci (NF Institut Pasteur; 1994). For Salmonella analysis, 25 g of sweet corn kernels were placed in a sterile stomacher bag with 225 ml of sterile buffered peptone water (Eur Pharm, Condà, Pronadisa, Spain). For other parameters, 10 g of sweet corn kernels were aseptically transferred into a stomacher bag filled with 90 mL of sterile buffered peptone water. Buffered peptone water was suspended by boiling for 1 min and complete dissolution. Buffered peptone water was sterilized in retort at 121°C for 15 min. Samples were homogenized for 1 min using a Stomacher (400 Circulator, SEWARD). Appropriate decimal dilutions of the resultant homogenate were prepared using buffered peptone water. Volume of inoculation was 0.1 mL for samples analyzed before sterilization treatments and 10 mL for samples analyzed after sterilization. For each parameter, measurements were done in duplicate and results were calculated by Equation 3 according to Standard NF ISO 7218(2007).

\[
N = \frac{\Sigma \text{colonies}}{V \text{mL} \times (n_1+0.1n_2) \times d_1}
\] (3)

In Equation 3, N represents the number of microorganisms expressed in CFU/g of sweet corn; \(\Sigma \text{Colonies}\) is the sum of colonies in Petri dishes retained; V is the volume inoculated into Petri dishes; \(n_1\) is the number of dishes considered at the first dilution retained; \(n_2\) represents the number of dishes considered at the second dilution retained and \(d_1\) is the factor of the first dilution retained.

Stability tests

Stability tests were carried out on all canned sweet corn samples processed at each thermal treatment according to AFNOR (NF V08-401; 1997). Two samples of sweet corn cans were incubated at 30 and 55°C respectively for seven and 21 days. The control was placed at ambient temperature (20 to 25°C). Macroscopic and microscopic analyses were done. Measurement of pH was done with 10 g of homogenized sample in 50 mL of distilled water. Difference of pH between incubated cans and control should not exceed to 0.5 units. Aerobic Mesophilic Total Count at 30°C, Yeasts and Molds, C. botulinum, Thermophilic and Mesophilic Bacillus were enumerated.

Shelf life study

Shelf life of canned sweet corn processed at five heat sterilization treatments was evaluated during 12 month of storage at room temperature by following the evolution of pH, yeasts and molds, aerobic mesophilic total counts, sulfide-reducing spores of Clostridium, thermophilic and mesophilic Bacillus.

Color analysis

Color measurements were made using a Minolta CR 410 Chroma Meter (Osaka, Japan) calibrated with a standard white plate. Color was evaluated on fresh sweet corn and after each sterilization treatment in triplicate for each sample. CIE* values for color lightness (\(L\)), greenness/redness (\(a^*\)) and blueiness/yellowness (\(b^*\)) were used to express color characteristic of samples. Total color difference (Delta E*) was calculated using Equation 4, where subscript “0” refers to the color reading of fresh sweet corn. Fresh sweet corn was used as the reference.

\[
\text{Delta E}^* = \left( (L_0 - L)^2 + (a_0 - a)^2 + (b_0 - b)^2 \right)^{1/2}
\] (4)

Ascorbic acid analysis

Ascorbic acid was determined on fresh sweet corn samples and after each sterilization treatment using official methods of analysis (AOAC, 1990).

Statistical analysis

All statistical analyses were performed using SPSS 20.0. (IBM stats software). The Student-Newman-Keuls(SNK) test was used to determine difference at \(\alpha=0.05\).

RESULTS AND DISCUSSION

Hygiene level of sweet corn samples before canning

Table 1 shows the level of aerobic mesophilic total counts (AMC) expressed in Log$_{10}$ CFU/g detected on sweet corn samples at different preliminary processing stage. The AMC was significantly highest after husking (5.4 log$_{10}$ CFU/g) and lowest after blanching (1.8 log$_{10}$ CFU/g). Cooling increased the AMC by 2 log$_{10}$ CFU/g, while cutting and washing increased the AMC by 0.2 and 0.6 log$_{10}$ CFU/g, respectively. There are no significant differences between cooling, cutting and washing operation while husking and blanching operations were statistically different. According to Pianetti et al. (2008), aerobic colony count does not relate to food poisoning and infections but is an indicator for food quality and shelf life. The aerobic bacterial count should be lower than 4 Log$_{10}$ CFU/g for safe consumption (Khadka et al., 2017).
The exterior of vegetables is normally contaminated with bacteria and fungi. This fact could explain the AMC values found in fresh-husked sweet corn ears. Data are similar to those reported by Abadias et al. (2008) in fresh-cut vegetables (4.3 to 8.9 log$_{10}$ CFU/g). Kumar et al. (2015) reported a level of AMC up to 8.4 log$_{10}$ CFU/g in freshly shelled sweet corn kernels. The initial microbial load of raw material varies less or more in number according to its nature, its origin and the conditions for obtaining, transporting, and preparing (Andre et al., 2005). Blanching reduced AMC by 3.6 log$_{10}$ CFU/g. Similar reduction in microbial load upon blanching (4 log$_{10}$ CFU/g) has been reported for sweet corn kernels by Kumar et al. (2015). Blanching is a thermal process designed to inactivate the enzymes responsible for generating off-flavors and odors and to stabilize texture and nutritional quality and destroy microorganisms (Bahceci et al., 2005). Furthermore, blanching is one of the stages of kernel technological production processes for consumer purposes (Szymanek et al., 2020). Many studies have demonstrated the positive effects of blanching on microbial quality of vegetables.

It is well established that fresh vegetables can be contaminated with pathogenic bacteria at any step from cultivation to consumption (Buyukunal et al., 2015). According to HACCP-TQM technical guidelines, raw foods containing < 4 log$_{10}$ CFU/g; 4-6.7 log$_{10}$ CFU/g; 6.7-7.7 log$_{10}$ CFU/g and > 7.7 log$_{10}$ CFU/g are rated as “good”, “average”, “poor” and “spoiled” respectively (Buyukunal et al., 2015). In our study, hygienic conditions of sweet corn samples were “average” after husking and cutting stages but “good” at blanching, cooling and washing steps. Therefore, to improve the hygiene level of sweet corn during canning, blanching was moved to the last operation before can filling. Blanched sweet corn kernels were directly filled into cans followed by exhausting and seaming steps.

**Effect of thermal sterilization on microbiological quality of canned sweet corn**

Thermal treatment applied during processing of canned foods should destroy microorganisms which cause spoilage and foodborne illness (Mishra and Sinha, 2018). In this study, the impact of five combinations of heating temperature and holding time on the microbiological quality of canned sweet corn was evaluated (Table 2). No microorganisms related to food spoilage and public health concerns were detected in all canned sweet corn samples regardless of treatment. Indeed, *C. botulinum* and its related sulfide-reducer spores, *Staphylococcus* aureus, *mesophilic* and thermophilic *Bacillus*, *B. cereus* and *Salmonella* were absent in canned sweet corn for all five sterilization treatments. Nevertheless, the AMC was 0.3, 0.5 and 1 Log$_{10}$ CFU/g in canned sweet corn after treatments B, C and D, respectively. These were below the maximum limit of AMC (1.7 log$_{10}$ CFU/g) allowed in canned vegetables (KEBS, 2016). The AMC acts as an indicator of food quality (Pianetti et al., 2008). Results indicated also the good hygiene level of sweet corn kernels before sterilization (all data were < 4 Log$_{10}$ CFU/g).

For heat thermal treatment validation, stability tests were performed on all canned sweet corn samples (Tables 3a and b). Results showed no micro-leaks, bending, flocking and opening gas release for canned sweet corn samples incubated at 30 and 55°C. Macroscopic examination of color, texture and odor were also normal after incubation at 30 and 55°C. For

### Table 2. Microbiological counts (Log$_{10}$ CFU/g) of sweet corn kernels (a) before and (b) after five different heat sterilization treatments.

| Microbiological parameters (Log$_{10}$ CFU/g) | Heating temperature (°C) and holding time (min) combinations | A | B | C | D | E |
|---------------------------------------------|-------------------------------------------------------------|---|---|---|---|---|
| Yeasts and Molds                             |                                                             | <1 nd | <1 nd | <1 nd | <1 nd | <1 nd |
| Aerobic Mesophilic total count at 30°C       |                                                             | 1.7 0 | 2.1 0.3 | 2.7 0.5 | 2.8 1 | 1.3 0 |
| Fecal coliforms                             |                                                             | <1 nd | <1 nd | 1.3 nd | 1.9 nd | <1 nd |
| Sulfide-reducer spores of *Clostridium*      |                                                             | <1 nd | <1 nd | <1 nd | <1 nd | < nd |
| *Clostridium botulinum*                      |                                                             | <1 nd | <1 nd | <1 nd | <1 nd | < nd |
| Pathogenic *Staphylococci* (aureus)          |                                                             | <2 nd | <2 nd | <2 nd | <2 nd | <2 nd |
| Fecal *Streptococci*                        |                                                             | <1 nd | 1.3 nd | 1.8 nd | 2.1 nd | <1 nd |
| *Mesophilic Bacillus*                        |                                                             | <1 nd | <1 nd | <1 nd | <1 nd | <1 nd |
| Thermophilic *Bacillus*                      |                                                             | <1 nd | <1 nd | 1 nd | <1 nd | <1 nd |
| *Bacillus cereus*                           |                                                             | <2 nd | <2 nd | <2 nd | <2 nd | <2 nd |
| Enterobacteriaceae at 37°C                  |                                                             | <1 nd | <1 nd | <1 nd | 1.85 nd | <1 nd |
| *Salmonella* (absence in 25 g)               |                                                             | nd nd | nd nd | nd nd | nd nd | nd nd |

A=121.1°C/4 min, B=118°C/40 min, C= 121.5°C/18min, D=125°C/8 min, E=125°C/12 min. a: before sterilization; b: after sterilization; nd: not detected.
### Table 3a. Stability tests: Macroscopic examination of canned sweet corn kernels.

| Parameter | Control incubated at ambient temperature | Samples incubated at 30°C | Control incubated at ambient temperature | Samples incubated at 55°C |
|-----------|------------------------------------------|---------------------------|-------------------------------------------|---------------------------|
| **Treatment A** | | | | |
| Micro leaks | | | | |
| Bending | | | | |
| Flocking | | | | |
| Opening gas release | | | | |
| Visual color | | | | |
| Texture | Normal | | | |
| Odor | | | | |
| **Treatment B** | | | | |
| Micro leaks | | | | |
| Bending | Absence | | | |
| Flocking | | | | |
| Opening gas release | | | | |
| Visual color | | | | |
| Texture | Normal | | | |
| Odor | | | | |
| **Treatment C** | | | | |
| Micro leaks | | | | |
| Bending | Absence | | | |
| Flocking | | | | |
| Opening gas release | absence | Low 1/2 | Absence | Absence |
| Visual color | | | | |
| Texture | Normal | | | |
| Odor | | | | |
| **Treatment D** | | | | |
| Micro leaks | | | | |
| Bending | Absence | | | |
| Flocking | | | | |
| Opening gas release | Absence | Low 1/2 | Absence | Absence |
| Visual color | Normal | Little trouble | Normal | Normal |
| Texture | | | | |
| Odor | Normal | | | |
| **Treatment E** | | | | |
| Micro leaks | | | | |
| Bending | Absence | | | |
| Flocking | | | | |
| Opening gas release | | | | |
| Visual color | Normal | | | |
| Texture | Normal | | | |
| Odor | | | | |

A=121.1°C/4min, B=118°C/40 min, C= 121.5°C/18min, D=125°C/8 min, E=125°C/12 min.

In treatment B, a pH difference > 0.5 between controls and samples was noticed and presence of thermophilic *Bacillus* in the samples incubated at room temperature and at 55°C. Canned sweet corn kernels sterilized with
Table 3b. Stability test: Microscopic examination and microbiological analysis of canned sweet corn kernels.

| Parameter                                                                 | Control incubated at ambient temperature | Samples incubated at 30°C | Control incubated at ambient temperature | Samples incubated at 55°C |
|---------------------------------------------------------------------------|------------------------------------------|---------------------------|------------------------------------------|---------------------------|
| **Treatment A**                                                           |                                          |                           |                                          |                           |
| Number of germs/20 fields*                                                | 0                                        | 0                         | 1                                        | 0                         |
| R-Factor*                                                                 |                                          |                           |                                          |                           |
| Yeasts and molds (CFU/g)                                                  |                                          |                           |                                          |                           |
| Aerobic Mesophilic total count at 30° (CFU/g)                             |                                          |                           |                                          |                           |
| Sulfide-reducer spores of *Clostridium* (CFU/g)                           |                                          |                           |                                          |                           |
| *Clostridium botulinum* (CFU/g)                                           |                                          |                           |                                          |                           |
| Mesophilic *Bacillus* (CFU/g)                                             |                                          |                           |                                          |                           |
| Thermophilic *Bacillus* (CFU/g)                                           |                                          |                           |                                          |                           |
| pH                                                                        | 6.86                                     | 6.82                      | 7.35                                     | 7.33                      |
| **Treatment B**                                                           |                                          |                           |                                          |                           |
| Number of germs/20 fields*                                                | 0                                        | 0                         | 2                                        | 2                         |
| R-Factor*                                                                 |                                          |                           |                                          |                           |
| Yeasts and Molds (CFU/g)                                                  |                                          |                           |                                          |                           |
| Aerobic Mesophilic total count at 30° (CFU/g)                             | 2                                        | 1                         | 2                                        | 2                         |
| Sulfide-reducer spores of *Clostridium* (CFU/g)                           |                                          |                           |                                          |                           |
| *Clostridium botulinum* (CFU/g)                                           |                                          |                           |                                          |                           |
| Mesophilic *Bacillus* (CFU/g)                                             | 0                                        | 0                         | 1                                        | 0                         |
| Thermophilic *Bacillus* (CFU/g)                                           | 1                                        | 0                         | 3                                        | 1                         |
| pH                                                                        | 6.62                                     | 6.65                      | 7.72                                     | 7.69                      |
| **Treatment C**                                                           |                                          |                           |                                          |                           |
| Number of germs/20 fields*                                                | 1                                        | 0                         | 1                                        | 2                         |
| R-Factor*                                                                 |                                          |                           |                                          |                           |
| Yeasts and Molds (CFU/g)                                                  |                                          |                           |                                          |                           |
| Aerobic Mesophilic total count at 30° (CFU/g)                             | 1                                        | 0                         | 1                                        | 2                         |
| Sulfide-reducer spores of *Clostridium* (CFU/g)                           |                                          |                           |                                          |                           |
| *Clostridium botulinum* (CFU/g)                                           |                                          |                           |                                          |                           |
| Mesophilic *Bacillus* (CFU/g)                                             | 0                                        | 0                         |                                          |                           |
| Thermophilic *Bacillus* (CFU/g)                                           |                                          |                           |                                          |                           |
| pH                                                                        | 6.97                                     | 6.96                      | 7.44                                     | 7.38                      |
| **Treatment D**                                                           |                                          |                           |                                          |                           |
| Number of germs/20 fields*                                                | 1                                        | 0                         | 1                                        | 0                         |
| R-Factor*                                                                 |                                          |                           |                                          |                           |
| Yeasts and Molds (CFU/g)                                                  | 0                                        | 1                         | 1                                        | 1                         |
| Aerobic Mesophilic total count at 30° (CFU/g)                             |                                          |                           |                                          |                           |
| Sulfide-reducer spores of *Clostridium* (CFU/g)                           |                                          |                           |                                          |                           |
| *Clostridium botulinum* (CFU/g)                                           |                                          |                           |                                          |                           |
| Mesophilic *Bacillus* (CFU/g)                                             |                                          |                           |                                          |                           |
| Thermophilic *Bacillus* (CFU/g)                                           |                                          |                           |                                          |                           |
| pH                                                                        | 7.01                                     | 6.97                      | 7.43                                     | 7.39                      |
| **Treatment E**                                                           |                                          |                           |                                          |                           |
| Number of germs/20 fields*                                                |                                          |                           |                                          |                           |
| R-Factor*                                                                 |                                          |                           |                                          |                           |
| Yeasts and Molds (CFU/g)                                                  |                                          |                           |                                          |                           |
| Aerobic Mesophilic total count at 30° (CFU/g)                             |                                          |                           |                                          |                           |
While heat treatment—such as the sterilization of sweet corn kernels at 121.1°C for 4 min, 118°C for 40 min, 121.5°C for 18 min, 125°C for 8 min, or 125°C for 12 min—can kill microorganisms, it also could have, in some cases, a negative impact on the overall quality of the final product. Sterilization treatments are not always microbiologically stable and may not achieve the target lethality (Tola and Ramaswamy, 2015).

Table 3b. Contd.

| Treatment | pH | F_{121.1}^{10} (min)* | C_{106}^{36} (min)* | C_{0}/F_{0} ratio |
|-----------|----|----------------------|---------------------|------------------|
| A         | 6.6| 6.4 ± 2.3            | 71.34 ± 8.22        | 11.15ab          |
| B         | 6.71| 21.8_{ab} ± 2.23    | 187.94_{ab} ± 12.67 | 8.62_{ab}        |
| C         | 6.82| 28.37_{ab} ± 12.26  | 164.9_{ab} ± 51.3   | 5.81_{a}         |
| D         | 6.74| 24.06_{ab} ± 3.24   | 110.91_{ab} ± 7.52  | 4.5_{a}          |
| E         | 6.82| 35.7_{a} ± 1.21     | 137.16_{ab} ± 1.9   | 3.84_{a}         |

*After coloration. A=121.1°C/4 min, B=118°C/40 min, C=121.5°C/18 min, D=125°C/8 min, E=125°C/12 min.

Sulfide-reducer spores of Clostridium (CFU/g)
Clostridium botulinum (CFU/g)
Mesophilic Bacillus (CFU/g)
Thermophilic Bacillus (CFU/g)

The sterilizing value (F-value) and cook value (C-value) are important parameters in thermal sterilization. The F-value is the measure of heat treatment in relation to nutrient degradation and textural changes that occur during processing. The cook value (C-value) is the measure of heat treatment in relation to nutrient degradation and textural changes that occur during processing. Sensory parameters, texture, and color of sterilized foods can be correlated with C-value/F-value ratio and can be used as an indicator to identify the process conditions that increase quality retention (Sreenath et al., 2009). In this study, treatments E, D, and C had statistically the lowest C_{0}/F_{0} ratio while treatments A and B had the highest ratio. Therefore, processing canned sweet corn kernels at 125°C for 12 min would result in better quality.

Effect on color

Color characteristics of fresh and canned sweet corn kernels after five sterilization treatments are presented in Table 5. All thermal treatments had significant effect on color characteristics. Results showed that canned sweet corn kernels sterilized at 118°C for 40 min had the lowest L* parameter which led to the darkest kernels. It is well established that corn is rich in carotenoids, which are responsible to their yellow color (Gallon et al., 2013; O’Hare et al., 2015; Liato et al., 2016). According to Song et al. (2018), there was a good relationship between visual color L* value and dominant carotenoid content in sweet corn juice during thermal processing, suggesting that the lightness color value could be applied for monitoring the changes in carotenoid contents. Non-
enzymatic browning at higher temperature could explain the darkness of color during heat treatment (Thakur et al., 2015). Furthermore, the combination of blanching and sterilization may contribute to the darkness color of kernels. Similar results were obtained by Liato et al. (2016) and Kachhadiya et al. (2018), where L* values decreased significantly after blanching and sterilization of sweet corn kernels. Treatment E had statistically the smallest total color change (Delta E* parameter) followed by treatment C while treatment D showed the largest total color change. According to Kachhadiya et al. (2018), the smallest total color change Delta E*, which can be assessed by human eye is 1.0, indicating noticeable change in color. A larger Delta E* denotes greater color change from the reference material (Mohammadi et al., 2008).

**Effect on vitamin C**

Table 6 presents the ascorbic acid content of fresh and canned sweet corn kernels sterilized at five different treatments. Ascorbic acid contents were statistically lower after treatments A, C, D and E. No significant difference was found between raw and processed kernels for treatment B. It is well established that vitamin C is unstable in foods and therefore processing and cooking caused significant losses depending on temperature, presence of oxygen, light, moisture content (Leskova et al., 2006). According to Jayathunge et al. (2015), vitamin C is very sensitive to light and oxygen and can be easily degraded by thermal treatment. The concentration of ascorbic acid was between 0.9-2.1 mg/100g in fresh kernels and between 0.53-0.77 mg/100g in canned kernels after sterilization treatment. These data were lower than those reported by Liato et al. (2016) for fresh sweet corn (3.34 mg/100g). On the other hand, ascorbic acid content of canned kernels in our study were higher than those reported by Liato et al. (2016) after treatment at 100°C for 22.27 min in electro activated brine solution (0.33 mg/100 g). Non vacuum-sealed canned sweet corn, heating and leaching into surrounding brine could explain losses in ascorbic acid noticed between fresh and canned sweet corn (Liato et al., 2016).

**Shelf life study**

Microbiological quality of canned sweet corn kept at room temperature was evaluated after five and 12 months of storage for each thermal treatment. Yeasts and Molds, sulfide-reducer spores of *Clostridium*, mesophilic and thermophilic *Bacillus* were absent in the canned sweet corn throughout the storage period regardless of treatment. The AMC after 12 months were up to 1 Log CFU/g for treatments A, D and E while they were less than those reported by Liato et al. (2016) for fresh sweet corn (0.33 mg/100g). Non vacuum-sealed canned sweet corn, heating and leaching into surrounding brine could explain losses in ascorbic acid noticed between fresh and canned sweet corn (Liato et al., 2016).

**Conclusion**

The effects of combinations of heating temperature and
Table 6. Ascorbic acid content in fresh and canned sweet corn kernels after five sterilization treatments.

| Treatment | A                       | B                      | C                       | D                       | E                       |
|-----------|-------------------------|------------------------|-------------------------|-------------------------|-------------------------|
|           | Fresh (mg/100 g)        | Canned (mg/100 g)      | Fresh (mg/100 g)        | Canned (mg/100 g)      | Fresh (mg/100 g)        | Canned (mg/100 g)      |
| Ascorbic  | 2.14 ± 0.05             | 0.77 ± 0.02            | 0.87 ± 0.04             | 0.73 ± 0.01             | 1.91 ± 0.05             | 0.66 ± 0.01             |
|           | ± 0.04                  | ± 0.02                 | ± 0.04                  | ± 0.01                  | ± 0.04                  | ± 0.01                  |
|           | 1.99 ± 0.04             | 0.67 ± 0.01            | 1.41 ± 0.15             | 0.53 ± 0.03             |                         |                        |

Means values ± standard deviation from two canning processing batches for each sterilization treatment. A=121.1°C/4 min, B=118°C/40 min, C=121.5°C/18 min, D=125°C/8 min, E=125°C/12 min. For each treatment, difference in letters (in lines) indicates significant difference at p≤0.05 (SNK test) between fresh and canned sweet corn.

holding time sterilization treatments on microbiological quality, color, vitamin C and shelf life were analyzed. Among the five sterilization regimes evaluated, treatment E (125°C for 12 min) will be recommended as processing sterilization parameters for canned sweet corn processing in this study. Indeed, canned sweet corn kernels sterilized at this condition were better in terms of microbiological stability and quality retention like color and vitamin C. The C-value/F-value ratio and total color change were also lowest at this temperature/time compared to other sterilization treatment. Nevertheless, canned sweet corn kernels were shelf stable after 12 months of storage at room temperature.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGMENTS

Support for this research was provided by USAID Cooperative Agreement number 685-A-0010-00194-00 from the US Agency for International Development.

REFERENCES

Abadías M, Usall J, Anguera M, Solsona C, Vinas I (2008).
models. Journal of Food composition and Analysis 19:252-276.
Liatv, Labrie S, Benali M, Alder M (2016). Study of the impact of a new hurdle technology composed of electro-activated solution and low heat treatment on the canned peas and corn quality and microbial safety. International Journal of Food Science and Technology 51:180-193.
Mishra DK, Shina NK(2018). Principles of vegetable canning. In Siddiq M, Uebersax MA (eds.), Handbook of Vegetables and Vegetable Processing. UK: Blackwell Publishing Ltd. pp.365-380.
Mohammadi A, Rafiee S, Emam-Djomeh Z, Keyhani A (2008). Kinetic Models for color changes in kiwifruit slices during hot air drying. World Journal of Agricultural Sciences 4(3):376-383.
More PG, Thakre SM, Khodke S (2018). Quality assessment of microwave blanched sweet corn kernels. International Journal of Agricultural Engineering 1:164-167.
NF EN ISO 4833-1 (2013). Microbiologie de la chaine alimentaire - Méthodéhorizontale pour le dénombrement des microorganismes - Partie 1: Comptage des colonies à 30°C par la technique d'ensemencement en profondeur.
NF EN ISO 6579 (2002). Microbiologie alimentaire. Méthodéhorizontale pour la recherche des Salmonella spp.
NF EN ISO 7218 (2007). Microbiologie des aliments. Exigences générales et recommandations - Chapitre 10.3 : Calcul et expression des résultats sur milieu solide.
NF EN ISO 7392 (2005a). Microbiologie des aliments. Méthodéhorizontale pour le dénombrement de Bacillus cereus: méthode par comptage des colonies à 30°C.
NF EN ISO 7937 (2005b). Microbiologie des aliments - Méthodéhorizontale pour le dénombrement de Clostridium perfringens - Technique par comptage des colonies.
NF Institut Pasteur (1994). Recherche dënombrement des Streptocoques fécaux. Recueil de normes françaises 1994 - ENSP / Institut Pasteur (Lille).
NF ISO 15213 (2003). Microbiologie des aliments- Méthodéhorizontale pour le dénombrement des bactériessulfito-réductrices se développant en conditions anaérobies.
NF ISO 21528 (2004). Microbiologie des aliments - Méthodeshorizontales pour la recherche le dénombrement des Enterobacteriaceae - partie 2: méthode par comptage des colonies.
NF V08-059 (2002). Microbiologie des aliments - Méthode de routine. Dënombrement des leuresetmoisissuress par comptage des colonies à 25°C.
NF V08-060 (2009). Microbiologie des aliments. Dënombrement des coliformséhémostatérolétrants par comptage des colonies obtenues à 44°C.
NF V08-401 (1997). Microbiologie des aliments - Contrôle de la stabilité des produitsappetisés et assimilés - Méthode de référence.
NF V08-602 (2011). Microbiologie des aliments - Dënombrement des spores dans les produitsalimentairesavanttraitementd'appartisation par comptage des colonies.
O'Hare TJ, Fanning KJ, Martin IF (2015). Zeaxanthin bio fortification of sweet-corn and factors affecting zeaxanthin accumulation and color change. Archives of Biochemistry and Biophysics 572:184-187.
Pacurar GL, Apahidean M, Has V, Russu F, Apahidean AI, Boanta A (2019). Researches on some biological and ecological characteristics of sweet corn. Bulletin UASVM Horticulture 76(1):84-71.
Pankaj SK (2016). Thermal processing of food. In. Ravishankar Rai V, Whiley Blackwell (eds.), Advances in Food Biotechnology. UK: pp. 681-692.
Pianetti A, Sabatini L, Citterio B, Pierfelici L, Ninfali P, Bruscolini F (2008). Changes in microbial populations in ready-to-eat vegetable salads during shelf life. Italian Journal of Food Science 20:245-254.
SCL (2019). Noslégumesfruits: le maïsdoux. Société de Culture Légumières. Available at http://www.scl.sn
Siddiq M, Pascale MA (2011), Peas, Sweet corn, and Green beans. In Sinha NK (eds.), Handbook of Vegetables and Vegetable Processing. UK: Blackwell Publishing Ltd, pp. 605-623.
Simpson R, Abakarov A (2009). Optimal scheduling of canned food plants including simultaneous sterilization. Journal of Food Engineering 90:53-59.
Song J, Meng L, Liu C, Zhang M (2018), Changes in color and carotenoids of sweet corn during high temperature heating. Cereal Chemistry 95(3):486-494.
Sow A, Lagnane O (2011). Culture maraîchère: maïsdoux. Créneauxporteurs du secteur primaire. Ministère de l’Economie des Finances, Direction de l’Appui du secteur privé. 18p.
Sreenath PG, Abhilash S, Ravishankar CN, Anandan R, Gopal TK (2009). Heat penetration characteristics and quality changes of Indian mackerel (Rastreiliger kanagurta) canned in brine at different retort temperatures. Journal of Food Process Engineering 32:893-915.
Stumbo CR (1973). Thermo bacteriology in food processing. New York: Academic Press. 336p.
Szymanek L, Dziwuliska-Hunek A, Tanas W (2020). Influence of blanching time on moisture, sugars protein and processing recovery of sweet corn kernels. Processes 8:340-346.
Thakur S, Kaur A, Singh N, Virdi AS (2015). Successive reduction dry milling of normal and waxy corn: grain, grit and flour properties. Journal of Food Science 80:1144-1155.
Tola YB, Ramaswamy HS (2015). Microbiological design and validation of thermal and high pressure processing of acidified carrots and assessment of product quality. Journal of Food Processing and Preservation 39:2991-3004.
Yu D, Bu F, Hou J, Kang Y, Yu Z (2016). A more improved growth and suppressed Fusarium infection in sweet corn. World Journal of Microbiology and Biotechnology 32(12):192.
Related Journals:

- African Journal of Biochemistry Research
- Journal of Microbiology and Antimicrobials
- African Journal of Microbiology Research
- International Journal of Biotechnology and Molecular Biology Research
- Journal of Bioinformatics and Sequence Analysis
- Journal of Biophysics and Structural Biology
- African Journal of Biochemistry Research
- Journal of Microbiology and Antimicrobials
- African Journal of Microbiology Research

www.academicjournals.org