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Table of Content

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
Richard Kipkorir Koskei, Beatrice Mugendi and Patrick Muliro 92

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

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African Journal of Food Science

Full Length Research Paper

Influence of temperature and time on microbial, physicochemical and functional quality of goat milk

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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, itcontains 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

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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 consideredas 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 15sleads 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 decreasesthe 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 collacted

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 goatmilk 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 temparetures (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 chemicalcharacteristics 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 meassured. 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 decribed by Igbabul et al. (2014). The media and distilled water and other tools were sterilized using autoclave, and using serial dilution to 10^3 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 ($P \leq 0.05$).

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 wes 4.5% and pasteurized goat milk was 5%. This difference in fat contentt 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 decrease 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 that 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

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^{a}	22.49^{c}	3.89^{b}	7.10^{b}	2.97^{a}
Y2	6.47^{ab}	25.33^{ab}	4.19^{ab}	7.65^{ab}	2.89^{ab}
Y3	5.57^{d}	24.78^{ab}	4.41^{a}	8.06^{a}	2.61^{b}
Y4	6.21^{b}	25.43^{ab}	4.23^{ab}	7.73^{ab}	2.84^{ab}
Y5	6.02^{b}	26.40^{a}	4.36^{a}	7.98^{a}	2.68^{b}
Y6	5.73^{c}	23.44^{bc}	4.39^{a}	7.99^{a}	2.60^{b}
Y7	6.47^{ab}	25.96^{a}	4.31^{a}	7.84^{ab}	2.89^{ab}
Y8	5.96^{b}	24.52^{ab}	4.28^{ab}	7.85^{ab}	2.88^{ab}
Y9	5.75^{c}	25.57^{a}	4.29^{ab}	7.86^{a}	2.87^{ab}
Y10	6.67^{a}	21.41^{d}	3.26^{c}	6.81^{c}	3.22^{c}

Y1 = 72^{o} /5s, Y2 = 72^{o}C /10s, Y3 = 72^{o}C /15s,Y4 = 80^{o}C /5s,Y5 = 80^{o}C /10s, Y6 = 80^{o}C /15s, Y7 = 85/5s, Y8 = 85/10s, Y9 = /15s, and Y10 as control.

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 consistentwith 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 protien 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 sterillization processes revealed significant influence on pH, titeritable 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 decreasein 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 microbila 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; Aguirrre 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 3. Physicochemical properties of pasteurized goat milk.

Parameter	Density	pH	Titeritable acidity	Freezing point
Y1	1.03^{b}	6.6^{a}	0.10^{a}	-0.4605^{ab}
Y2	1.03^{b}	6.5^{a}	0.12^{a}	-0.493^{abcd}
Y3	1.05^{bc}	6.4^{a}	0.11^{a}	-0.539d
Y4	1.08^{a}	6.3^{b}	0.10^{a}	-0.501 ^{abcd}
Y5	1.03^{b}	6.3^{b}	0.11^{a}	0.5195^{cd}
Y6	1.04^{bc}	6.2^{c}	0.11^{a}	-0.452^{a}
Y7	1.06^{d}	6.6^{a}	0.10^{a}	-0.51^{bcd}
Y8	1.05^{bc}	6.5^{a}	0.11^{a}	-0.48^{abc}
Y9	1.06^{d}	6.4^{a}	0.11^{a}	-0.511^{cd}
Y10	1.03^{b}	6.7^{a}	0.10^{a}	-0.384^{e}

Y1 = 72°C /5 s, Y2 = 7°C /10 s, Y3 = 72°C /15 s,Y4 = 80°C /5 s,Y5 = 80°C /10 s, Y6 = 80°C /15 s,Y7 = 85/5 s, Y8 = 85/10 s, Y9 = /15 s, and Y10 as control.

increased non-fat solids. This differencein increasing non-fat solid due to the temperature effect on evaporated water from milk led todecreased water content, and change in nature of carbhydrate 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 olids, lactose and specific gravity values, and deceased 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 protien 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 sterillization processes revealed significant influence on pH, titeritable 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, Y3was 6.4, Y4 was 6.3, Y5 was 6.3, Y6 was 6.2, Y7 was6.6, Y8 was 6.4, and Y9 was 6.5. These results showed that the pH of Y3 is higher comparedto other samples, and pH values of Y6 sample was lowest, 6.2. From these results there was significant diference between heated goat milk and control. These results shows 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 respectivly. 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 Y1Y2 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 samplerespectively. 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 titeritable acidity in goat milk. Conversely, there was no significant effect on titeritable 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 sterillization processes revealed significant influence on pH, titeritable 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 (x10^{3}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 respectivly. 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 loded 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^{3} cfu/ml

Table 4. Micorobiology analysis of heated goat milk.

Parameter	TPC10^3cfu/m/	Yeast	Mould
Y1	8.6^{a}	5.0^{a}	4.3^{a}
Y2	7.0^{b}	4.0^{ab}	4.0^{a}
Y3	6.0^{c}	3.3^{b}	3.3^{a}
Y4	6.0^{c}	2.3^{bc}	5.3^{a}
Y5	5.3^{d}	2.3^{d}	5.0^{a}
Y6	5.3^{d}	2.3^{d}	3.6^{a}
Y7	4.6^{e}	1.3^{f}	4.3^{a}
Y8	4.4^{e}	2.0^{e}	5.0^{a}
Y9	3.6^{f}	2.3^{d}	3.3^{a}
Y10	12.1^{g}	7.5^{g}	10.0^{b}

respectively. Therefore, the microbiological results highlighted that pasteurization was effective to reduce microbial loadin 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 1×10^3cfu/ml and *Staphylococcus aureus* of 1×10^2 cfuL. The total plate count (TPC) has a maximum 1×10^6cfu/ml. In addition, the pasteurization at 85°Cfor 15sis 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. Onthe other hand, it decreases protein, fat, pH, and density, whileit increases the lactose and non-fat solids of goat milk.Therefore, the 85°C for 5sincreased the level of non-solids and lactose in goat milk issuitable for producing goat milk yogurt powder.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Effects of processing methods on fatty acid profiles and biochemical compounds of Arabica coffee cultivars

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Coffee cherries were processed traditionally by the wet method that uses large quantities of water and eco-friendly methods that utilizes 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 16.88%, 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

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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). Semidry 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 $\pm$ 1%. The dry parchments were then packed and sealed in polythene bags and stored in a freezer at -18^{0}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 gdw.

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

Table 1. Concentrations of fatty acids profiles in green coffee for SL 28 cultivar processed by different pulping methods (mg/100 gdw).

Fatty acids	Wet pulper	Hand pulper	Eco-pulper
Palmintic acid	8.14 + 2.53[a]	7.29 + 2.12[b]	10.37 + 2.31[a]
Stearic acid	4.14 + 1.6[b]	3.43 + 1.94[b]	5.06 + 0.57[a]
Oleic	2.50 + 1.06[ab]	1.93 + 0.80[b]	3.79 + 0.71[a]
Linoleic acid	19.30 + 2.39[a]	13.82 + 1.40[b]	19.82 + 3.64[a]
Linolenic acid	1.76 + 0.37[b]	1.80 + 0.65[b]	2.52 + 0.76[a]

[1]values are means (± SD) of triplicate determinations. [2]means designated by different letters in a row are significantly different at (P <0.05).

Table 2. Concentrations of fatty acids profiles in green coffee samples for Ruiru 11 cultivar processed by different pulping methods (mg/100 gdw).

Fatty acids	Wet pulper	Hand pulper	Eco-pulper
Palmintic acid	7.82 + 1.54[a]	7.07 + 0.78[a]	7.25 + 1.68[a]
Stearic acid	2.44 + 1.35[a]	2.16 + 0.72[a]	2.73 + 0.48[a]
Oleic	1.59 + 0.47[a]	1.69 + 0.27[a]	1.79 + 0.27[a]
Linoleic acid	16.87 + 4.29[a]	15.67 + 2.25[a]	16.88 + 3.20[a]
Linolenic acid	1.27 + 0.34[a]	1.07 + 0.28[a]	1.27 + 0.38[a]

[1]values are means (± SD) of triplicate determinations. [2]means designated by different letters in a row are significantly different at (P <0.05).

detected at 324 nm for chlorogenic acid, and 263 nm wavelengths for caffeine and trigonelline. The elution time was 5 min and 6 min for trigonelline and caffeine respectively. Identification was achieved by comparison of retention times (Rt) of samples with those of the standards.

Statistical analysis

All treatments were done in triplicates and analysis of data evaluated using the Statistical Package for Social Scientist (SPSS version 18). Analysis of variance (ANOVA) was conducted, and the differences between group means analyzed using the Least Significant Difference (LSD). Statistical significance was established at p≤ 0.05.

RESULTS AND DISCUSSION

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: palmintic, stearic acid, oleic acid, linoleic acid and linolenic acid. Linoleic acid showed the highest concentration with a range of 13-19 mg/100 g, followed by palmitic acid (7-10 mg/100 g), stearic acid (2-5 mg/100 g), oleic acid (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-puper 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 palmintic 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

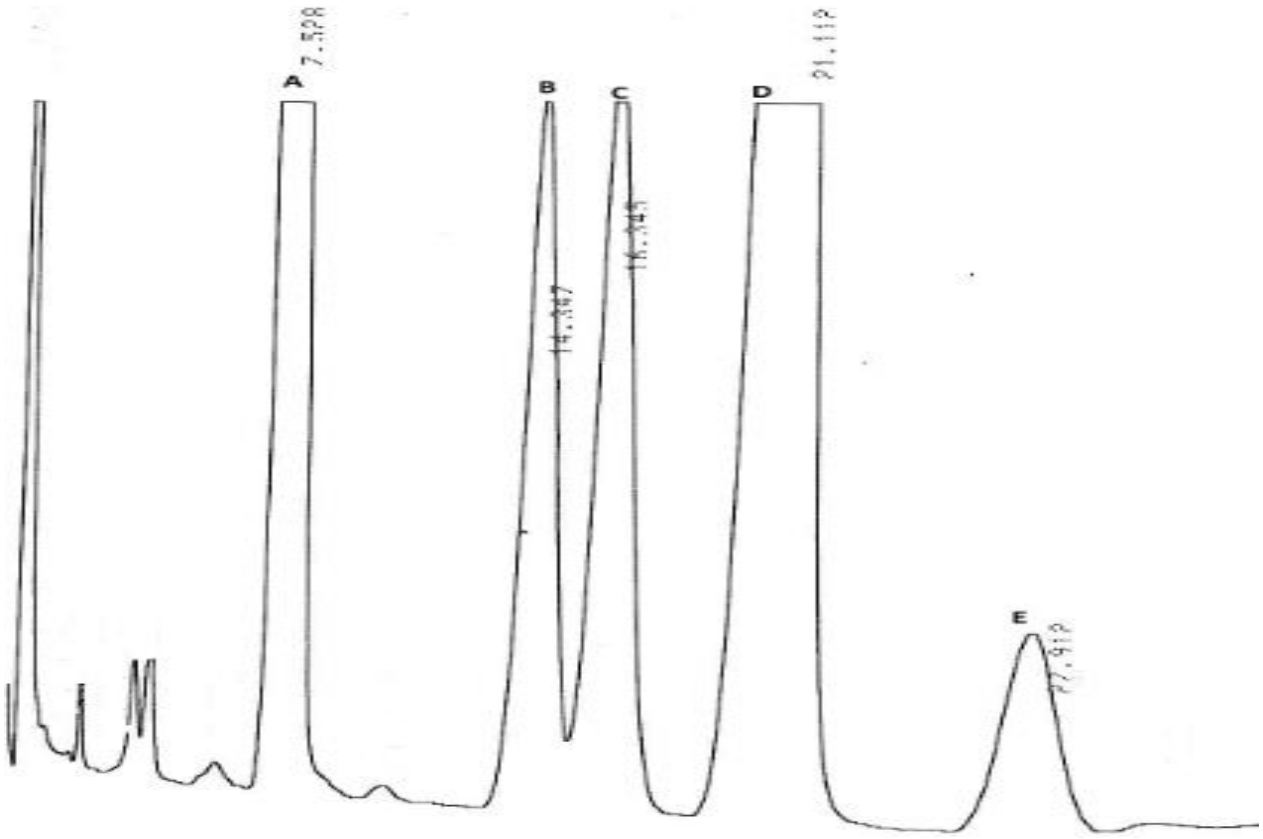

Figure 1. Chromatograph for the fatty acids profiles in green coffee samples: A-Palmintic acid, B-stearic acid, C-Oleic acid, D-Linoleic acid, E-Linolenic acid.

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, diacyglycerol 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

Table 3. Biochemical contents for SL 28 and Ruiru 11samples processed by three different processing methods.

	Cultivar	Wet pulper	Hand pulper	Eco-pulper
Trigonelline %	SL 28	1.26 + 0.10[a]	1.24 + 0.06[a]	1.29 + 0.10[a]
	Ruiru 11	1.28 + 0.10[a]	1.36 + 0.12[a]	1.36 + 0.19[a]
Caffeine %	SL28	1.36 + 0.05[a]	1.35 + 0.02[a]	1.29 + 0.04[a]
	Ruiru 11	1.30 + 0.09[a]	1.45 + 0.18[a]	1.34 + 0.13[a]
Chlorogenic acid %	SL28	5.34 + 0.14[a]	5.34 + 0.14[a]	5.44 + 0.28[a]
	Ruiru 11	5.31 + 0.23[a]	5.34 + 0.07[a]	5.46 + 0.09[a]

[1]values are means (± SD) of triplicate determinations. [2]means designated by different letters in a row are significantly different at (P <0.05).

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 pyrroles 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.

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

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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

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Table 1. Acceptability level of meat and fish sources of protein in pepper soup dishes (Mean ± SD).

Sample code	Source of protein	Aroma	Appearance	GA	Sensory attribute		Overall acceptability
					Visual texture	Taste	
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	3.48±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.

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 pottage, 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 mystristica* (Iwo), *Tetrapleura tetreapera* (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 used in generous amounts 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. mystristica* (Iwo), (2) *T. tetreapera* (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

Table 2. Comparative analysis of pepper soup samples by gender.

Summary of multi-t-test analysis 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	.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 of males was 4.15±0.49 signifying very good, while the female had a mean score of 3.95±0.69 signifying 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.

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

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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. spp*saccharata*), 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

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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 sub-sector 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. An average number of 44 cans of prepared sweet corn kernels were implied in thermal sterilization. Canned sweet corn kernels were sterilized 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 coming-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.

$$F = \int_0^t 10^{\frac{T-121.1}{z}}\ dt \quad (1)$$

Where t represents time (min), Z is the temperature sensitivity of the target microorganism (for *Clostridium botulinum*, Z=10°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).

$$C = \int_0^t 10^{\frac{T-100}{z}}\ dt \quad (2)$$

Microbiologicalquality 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)	$5.4^{c} \pm 0.3$	$1.8^{a} \pm 0.6$	$3.8^{b} \pm 0.7$	$4^{b} \pm 0.7$	$3.4^{b} \pm 1$

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 EN 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, Conda, 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 prepared by suspending 16.1 g of the medium in 1 L of distilled water and boiling for 1 min until 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).

$$N = \frac{\Sigma\, colonies}{Vml\ X\ (n1+0.1n2)\ X\ d1} \quad (3)$$

In Equation 3, N represents the number of microorganisms expressed in CFU/g of sweet corn; ∑ Colonies is the sum of colonies in Petri dishes retained; $V_{ml}$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-reducer 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 blueness/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.

$$\text{Delta } E^* = ((L_0-L)^2 + (a_0-a)^2 + (b_0-b)^2)^{1/2} \quad (4)$$

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 α=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).

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	
	a	***b***	***a***	***b***	***a***	***b***	***a***	***b***	***a***	***b***
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	<1	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/4min, 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.*

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 (Bahçeci 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* pathogens, 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 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	Absence			
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	Normal			
Odor				
Treatment E				
Micro leaks				
Bending	Absence			
Flocking				
Opening gas release				
Visual color				
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.

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*		0		
Yeasts and molds (CFU/g)				
Aerobic Mesophilic total count at 30° (CFU/g)	0	1	2	0
Sulfide-reducer spores of *Clostridium* (CFU/g)				
Clostridium botulinum (CFU/g)		0		
Mesophilic *Bacillus* (CFU/g)				
Thermophilic *Bacillus* (CFU/g)				
pH	6.86	6.82	7.35	7.33
Treatment B				
Number of germs/20 fields*				
R-Factor*		0		
Yeasts and Molds (CFU/g)				
Aerobic Mesophilic total count at 30° (CFU/g)	2	1	2	2
Sulfide-reducer spores of *Clostridium* (CFU/g)		0		
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*				
R-Factor*		0		
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)		0		
Mesophilic*Bacillus* (CFU/g)				
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*	0		0	
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)		0		
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*		0		
Yeasts and Molds (CFU/g)				
Aerobic Mesophilic total count at 30° (CFU/g)				

Table 3b. Contd.

Sulfide-reducer spores of *Clostridium* (CFU/g)				
Clostridium botulinum (CFU/g)				
Mesophilic *Bacillus* (CFU/g)				
Thermophilic *Bacillus* (CFU/g)				
pH	6.6	6.71	6.82	6.74

*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.

Table 4. Sterilizing value (F_0-value) and cook value (C_0-value).

Treatment	$F_{121.1}^{10}$(min)*	C_{100}^{36} (min)*	C_0/F_0 ratio
A	6.4^{a} ± 2.3	71.34^{a} ± 8.22	11.15^{b}
B	21.8^{ab} ± 2.23	187.94^{b} ± 12.67	8.62^{ab}
C	28.37^{b} ± 12.26	164.9^{ab} ± 51.3	5.81^{a}
D	24.06^{ab} ± 3.24	110.91^{ab} ± 7.52	4.5^{a}
E	35.7^{b} ± 1.21	137.16^{ab} ± 1.9	3.84^{a}

Means values ± standard deviation from two canning processing batches for each sterilization treatments. 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 column, difference in letters indicates significant difference at p≤0.05 (SNK test).

treatment B were not microbiologically stable and was not validated in our conditions of study.

Sterilizing values (F-value) and cook values (C-value)

Sterilizing values (F-value) and cooking values (C-value) calculated from core temperatures recorded at the cold point of canned sweet corn kernels during thermal sterilization treatments are presented in Table 4. F-values for treatments C and Ewere significantly higher than treatment A. In thermal processing, pathogen survival depends on temperature and treatment time used to achieve the target lethality (Tola and Ramaswamy, 2015). According to Heinz and Hautzinger (2007), thermal processing of low-acid foods (pH > 4.6) such as sweet corn, conventionally uses sterilizing values equal to 2.58 min for destroying the spores of *C. botulinum;* but more severe conditions are still in need to control spoilage organisms because of mesophilic spore-forming bacteria (*Clostridium sporogenes)* and thermophilic bacteria (*Bacillus stearothermophilus*) which are more resistant than *C. botulinum* and could cause food spoilage (Stumbo, 1973)..Sterility can generally be accomplished when the number of viable spores in the population of mesophilic spore-forming bacteria is 10^{-4} after treatment time (Liato et al., 2016).While heat sterilization can kill microorganism, it also could have, in most cases, a negative impact on the overall quality of product (Mishra and Sinha, 2018).

The cook value (C-value) is a parameter for evaluating the impact of thermal processing on food. According to Sreenath et al. (2009), C-value is the measure of heat treatment with respect to nutrient degradation and textural changes that occur during processing. Thus, the cook value (C-value) should be minimized at any given F-value. 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-

Table 5. Color characteristics in fresh kernels and canned sweet corn kernels after five sterilization treatments.

Treatment	Sample	L*	a*	b*	Delta E*
A	Fresh	49.37^{b}± 0.03	1.29^{b}± 0.015	30.15^{b}± 0.03	12.8^{c}± 0.01
	Canned	40.12^{a}± 0.04	1.23^{a}± 0.01	21.28^{a}± 0.038	
B	Fresh	47.27^{b}± 0.006	0.95^{a}± 0.006	28.55^{b}± 0.006	14.94^{d}± 0.02
	Canned	36.89a± 0.07	2.87^{b}± 0.011	17.97^{a}± 0.025	
C	Fresh	47.6^{b}± 0 .006	0.99^{a}± 0.01	28.45^{b}± 0.015	7.62^{b}± 0.015
	Canned	40.23^{a}± 0.01	1.99^{b}± 0.21	26.77^{a}± 0.15	
D	Fresh	44.45^{a}± 0.015	0.34^{a}± 0.006	24.92^{a}± 0.011	16.18^{e}± 0.01
	Canned	51.24^{b}± 0.015	1.88^{b}± 0.01	39.52^{b}± 0.025	
E	Fresh	45.91^{b}± 0.006	0.43^{a}± 0.055	26.72^{a}± 0	6.82^{a} ± 0.014
	Canned	39.28^{a}± 0	1.86^{b}± 0.01	27.55^{b}± 0.025	

Means values ± standard deviation from two canning processing batches for each sterilization treatments. 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 color parameter (in column), difference in letters (in lines) indicates significant difference at p≤0.05 (SNK test) between fresh and canned sweet corn for each treatment.

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_{10} CFU/g for treatments A, D and E while they were less than 1 Log_{10} CFU/g for treatments B and C. The level of AMC in canned sweet corn kernels indicates their high hygiene level. In this study, pH values of canned sweet corn kernels were 7 to 7.2, which decreased after 12 months of storage, by 0.7, 1.1, 0.5, 0.3 and 0.1 pH units respectively for treatments A, B, C, D and E. Thus, treatment at 125°C exhibits the lowest variation in pH level. Kumar et al. (2015) had found pH value of 6.4 and 6.7 for fresh and processed sweet corn kernels.

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	Canned	Fresh	Canned	Fresh	Canned	Fresh	Canned	Fresh	Canned
Ascorbic acid (mg/100 g)	2.14^{b} ± 0.05	0.77^{a} ±0.02	0.87^{a} ± 0.04	0.73^{a} ± 0.01	1.91^{b} ± 0.05	0.66^{a} ± 0	1.99^{b} ± 0.04	0.67^{a} ± 0.01	1.41^{b} ± 0.15	0.53^{a} ± 0.03

Means values ± standard deviation from two canning processing batches for each sterilization treatments. 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.

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