Nutritional Value and Quality Standard of Popcorn Cooked by Microwave and Conventional Heating

Seerwan A. Abdullah

Food Technology Department, College of Agricultural Engineering Sciences, Salahaddin University, Iraq.

Email: serwan.abdullah@su.edu.krd

Abstract

The objectives of this study were to examine microwave oven (MO) and entails conventional heating (CH) under normal condition and difference times to produce popped of popcorn in some parameters of expansion popping volume, un-popped kernels and flake size, as well as the preservation of nutritional value and sensory tests of two types of popcorn (A and B), which were bought from local market and used. The results obtained that the size/shape of samples A and B were 6.31 mm$^3$ (Medium Round (MR)) and 5.95 mm$^3$ (Medium Flat (MF)), respectively. The highest significant of expansion volume was recorded in sample (A) under cooked by (MO) after 4 min (16.55 cm$^3$/g) whereas, sample (B) under cooked by (CH) after six minutes (7.19 cm$^3$/g) was recorded lowest expansion volume. The flake size values of both samples (A) and (B) after (MO) were ranged between 1.88-2.18 and 1.72-1.98. The percentage of un-popped kernel was dramatically decreased from 30.67 to 1.67% and 38.67 to 1.66 % by (MO) and 10 to 1% and 7 to 1% by (CH) with increased time from 4 to 6 min of popping in both samples. Otherwise, the highest variation value of carbohydrate, oil and protein were observed (2.72, 1.51 and 0.33) respectively, in sample (A) under (CH) after 6 min, while the lowest variation value of carbohydrate was recorded (0.12,) in sample B under cooked by (MO) after four minutes, as well as the lowest variation values of oil and proteins were investigated (0.15 and 0.03) in sample (A) under cooked by (MO) after 4 min. Regarding the minerals (Fe and Zn) were slightly decreased with increased time of popping. Hence the highest values for each parameters of tenderness, crispiness, adhesives and overall acceptance were observed (8.33, 8.33, 9.0 and 8.55), respectively, in sample (A) by used (MO) for 5 min.

Keywords: Quality, Popcorn, Microwave, Heating.

1. Introduction

Popcorn is the most important popular snack foods made from corn for consumers in the world [1,2]. Behind a commonly snack food, it also is nutritious snack food with excellent functional properties since it is low in energy and high source of fiber. Many researches explained the physiochemical properties of popped popcorn that is included carbohydrate, protein, fat, crude fiber and ash content. In addition, they reported minerals, vitamins, fatty acid and amino acid composition [3,4]. Moreover, researchers [5-8], reported that all factors affected the quality of popcorn, which are included variety, kernel size and shape as well as kernel density and damage, pericarp thickness moisture content, popping methods and temperature. High popping expansion volume (HEPV) in popcorn (Zea mays L.) is correlated with enjoyable for the consumer attributes due to the final product is sold by volume, for that was the main reason the popcorn expansion capacity is the critical properties of the quality due to the maximum expansion value when popped after heating [9].

Popcorn pops because when it is heated up, the water inside the kernels expands turning into steam increasing the pressure extremely. When the temperature reaches a certain point approximately (175 to 200 °C) the outer shell ruptures, causing the inside to turn into as it expands, the starch gelatinizes and then expands with the rapid burst of the kernel and cools down. Moreover, Sensory tests are involves tenderness, crispiness, flavor and taste will be changed depend on the methods of heating [1,10]. Popping methods other points influence on the expansion volume, flake size an un-popped kernel [11].

In general, there are several trials are conducted using the conventional heating and microwave oven. During the last few decades, with alter conventional processing technology, microwave heating as innovative thermal technologies have been developed. Constant and volumetric heating in which thermal energy is produced from inside to the surface, reduced process time, fast heat transfer, costs and sanitization times are the advantages of this method. Several researches, [12,13] have been showed that the product have higher quality than those of product treated with conventional heating. The microwave oven has become very commonly among consumers. A large number of households and businesses in America is used extensively worldwide microwave popcorn.
The softness and cracks of popcorn pops depend on the heat the kernel, in view of the moisture to outflow slowly rather than popping out rapidly, when the kernels are cooked progressively, starting at a low heat as well as when the heat is non uniform, the popcorn kernel will be exposed a burnt, un-popped and a semi-popped [1]. On the other hand, previous studies were utilized the standard pressure cooker and a household microwave oven to show that the effect of thermodynamic on pressure to decrease pressure surrounding the popcorn as well as lead to increase the final expansion volume of popped kernel.

Although not much published data is available on the nutrient value on the popping popcorn performance in microwave oven and conventional heating in our location. The goal of this paper is to compare the conventional heating and microwave heating under normal condition to produce popped of popcorn as well as to obtain maximum expansion volume, flake size and minimizing un-popped of popcorn production. Hence, minimally loss of nutritional value, and sensory evaluation in popped of popcorn by both modes.

2. Materials and Methods

In this study two types of popcorn were bought from local market and used. For conducting popping experiments, weight of 100 kernels of corn and then popping (without adding salt and oil) was performed for popping by two methods, conventional heating and microwave oven method. The kernel samples were put in glass pot and covered with glass as well as put in microwave oven at power level (100%) for 4, 5 and 6 minutes of popping time by this method. For the second method, conventional heating the cooking stainless steel pan with cover was heated by using electric energy. The temperature was approximately 200 ± 05 °C, during popping and continued with the 4, 5 and 6 minutes.

3. Physiochemical Tests

To obtain mass of one thousand kernels weight (g), selecting hundred kernel weight (g) randomly was measured and multiplying the result by ten. In addition, the length (L), width (W) and thickness (T) were measured with digital calipers as well as diameter ratio, geometric and sphericity of seeds were calculated.

\[
\text{Diameter ratio (mm)} = \frac{L}{W} \\
\text{Geometric} = \left(\frac{L \times W \times X}{1} \right)^{1/3}
\]

3.1. Expansion volume, the flake size and percent of un-popped kernels

There are three major quality parameters of curiosity to industrial. The following three equations are used to analyze popcorn data [9].

\[
\text{Expansion Popping volume} = \frac{\text{Total popped volume (cm}^3\text{)}}{\text{Original sample weight (g)}}
\]

\[
\text{Flake size} = \frac{\text{Total popped volume (cm}^3\text{)}}{\text{Number of popped kernels}}
\]

\[
\text{% Un-popped} = \frac{\text{Number of un-popped kernels} \times 100}{\text{Original number of kernels}}
\]

3.2. Moisture content

According to [14], Moisture content is determined by oven drying at 103 C, and cooling the samples were allowed it in desiccators before final using weighing for corn before cooking.

3.3. Protein content

Determine of protein content in popcorn samples by a standard Kjeldhal protein analysis [15] (AACC, 1995), before and after cooked.

3.4. Oil Content

According to the [16]. Soxhlet extraction was used to determine the percent-by-weight of oil in kernel of popcorn and popping pop after cooking by microwave and conventional heating at different time individually. The kernels were grounded
using a coffee grinder and known weight was taken to extract the oil using Soxhlet system using Diethyl ether solvent using Hexane as a solvent.

3.5. Total Carbohydrate content
To calculate total carbohydrate content in kernel of popcorn was used by [14] due to the following equation.

\[
\text{Carbohydrate (\%) } = 100 - [(\% \text{ moisture} + \% \text{ fat} + \% \text{ protein} + \% \text{ dietary fiber} + \% \text{ ash})]
\]  

(6)

3.6. Ash contents
In each sample ash was measured as a total inorganic matter according to the procedure given [14].

3.7. Heat Capacity (\(C_p\)) and thermal conductivity (\(T_c\))
There were calculated for each samples before cooking according to the following equations [18].

\[
C_p = 1.424 X_h + 1.549 X_p + 1.675 X_f + 0.837 X_a + 4.18 X_w
\]

(7)

\[
T_c = 0.25 X_h + 0.155 X_p + 0.16 X_f + 0.135 X_a + 0.58 X_w
\]

(8)

\(X_h\) is a carbohydrate content, \(X_p\) is a protein content, \(X_f\) is a fat or oil content, \(X_a\) is an ash content and \(X_w\) is a moisture content.

3.8. Minerals content (Fe and Zn)
According to [18], Minerals concentration (Fe and Zn) were measured by utilized X-ray fluorescence (XRF). Sample preparation that include drying, grinding, and pressing into a pellet and then recorded.

3.9. Sensory Tests
According to [19], Sensory tests are performed on the popped kernels products. Panelists ask to rate each samples, its appearance, tenderness, crispness, adhesiveness to teeth, and overall acceptability using a 10-point hedonic scale, with the scores ranging from 1-2 = dislike extremely, 3-4 = dislike slightly, 5= neither like nor dislike, 6-7 = like slightly and 8-10= like extremely.

3.10. Statistical analysis
All experiments were carried out in triplicates and presented and using XLSTATY 2016 version 02.28451. The data were statistically analyzed by Duncan's multiple range tests at 5% significance level.

4. Results and Discussion

4.1. Physical and thermo-physical parameters
The results for the physical parameters, chemical composition and thermo properties of the two samples (A) and (B) of seed corn are presented in Table 1. Length, width and thickness of sample (A) were slightly higher than in sample (B). Furthermore, the results obtained from this research indicated that the size/shape of samples (A) and (B) were 6.31 mm\(^3\) (Medium Round (MR)) and 5.95 mm\(^3\) (Medium Flat (MF)), respectively. Researcher [20] reported regarding of three different kernel sizes/shapes 4.5-5.5 mm (SF and SR), 5.5-6.5 mm (MF and MR) and 6.5= mm (LF and LR) to investigate the shape of the seed corn. Consequently, the diameter ratio and sphericity in this study were in line with [9,21] and dissimilar with [22]. In addition in test weight of 1000 kernels in both samples, the weight of 1000 kernel in sample (A) slightly lower than in sample (B). This result was dissimilar with the above researchers for the 1000-kernel weight parameter, as well as this various is related to the types of seed corn and sample preparation. Although, results of determination of chemical compositions are summarized in Table 1. The percentage of components of kernel of popcorn, carbohydrate and protein contents were maximum (73.61 and 9.46\%) in kernel of popcorn (sample B) compared with kernel of popcorn (sample A). In contrast, percentage of oil, ash and moisture contents were minimum values.
(4.77, 2.31 and 9.85%) respectively, in sample (B) compared with sample (A). This result indicated that nutrient contents depended on type of samples. Many of the researchers observed that the popping quality affected by several factors, moisture contents, physical properties such as shape/size of kernel, weight of kernels, thickness of pericarp, cooking sample methods as well as structure of the kernel. [23–25].

Table 1. Physiochemical and thermo properties of kernel of popcorn before cooking.

| Parameters                          | Kernel of Popcorn (Sample A) | Kernel of Popcorn (Sample B) |
|------------------------------------|------------------------------|------------------------------|
| Length (L) (mm)                    | 8.90                         | 8.17                         |
| Width (W) (mm)                     | 4.85                         | 4.59                         |
| Thickness (T) (mm)                 | 6.14                         | 5.66                         |
| Geometric (L x W x T)^{1/3}        | 6.31                         | 5.95                         |
| Sphericity (L x W x T)^{1/3}/L    | 0.720                        | 0.729                        |
| Diameter Ratio L/W (mm)            | 1.84                         | 1.78                         |
| Moisture (%)                       | 149.6                        | 150.84                       |
| Carbohydrate (%)                   | 72.60                        | 73.61                        |
| Protein (%)                        | 8.40                         | 9.46                         |
| Oil (%)                            | 4.95                         | 4.77                         |
| Ash (%)                            | 2.90                         | 2.31                         |
| Heat capacity                      | 173.72                       | 170.57                       |
| Thermal conductivity              | 27.10                        | 26.66                        |

Thermal properties of foods is a crucial for research and engineering application such as heating and cooling. To investigate the predict heat transfer rate from microwave oven and conventional heating to the food due to the thermal properties of food such as heat capacity and thermal conductivity. According to equations (5 and 6) the specific heat, and thermal conductivity for both samples A and B, 173.72 and 170.57, 27.1 and 26.66 respectively. The results investigated that the value of heat capacity is increased with increase the components of samples especially, the water content due to the specific heat of water higher than the specific heat of other components [26]. Otherwise, in this study the physiochemical properties of popped popcorn in some parameters as nutrients value was slightly changed under cooked by microwave and conventional heating at different times. From the Table 2, statistically analysis, the results showed that the ash content in samples A and B of cooked by both methods were observed non-significant values. However, the value of all component was decreased as the time increased from 4 to 6 min of popping. The highest variation value of carbohydrate, oil and protein before and after popping were observed (2.72, 1.51 and 0.33) respectively, in sample (A) under conventional heating after 6 min, while the lowest variation value of carbohydrate before and after popping was recorded (0.12,) in sample (B) under cooked by microwave oven after 4 min, as well as the lowest variation values of oil and proteins before and after popping were investigated (0.15 and 0.03) in sample (A) under cooked by microwave oven after 4 min. The results in this study indicated that the microwave oven was better than the conventional heating for the preservation of chemical compositions due to its volumetric and uniform heating and significant reduction in cooking time. However, efficiency of microwave depend on the wavelength of microwave, moisture contents in food.

Table 2. Physiochemical properties of samples under cooked by microwave oven (MO) and conventional heating at different times.

| Samples | Time (min) | Cooked by (MO & CH) | Carbohydrate (%) | Oil (%) | Protein (%) | Ash (%) |
|---------|------------|---------------------|------------------|---------|-------------|---------|
| A       | 4          | Microwave oven (MO) | 71.82 abc        | 4.8 a   | 8.37 abc    | 2.43 a  |
|         | 5          | Microwave oven (MO) | 71.04 bc         | 4.72 a  | 8.31 bcd    | 2.31 a  |
|         | 6          | Microwave oven (MO) | 70.47 c          | 4.27 abc| 8.23 cd     | 2.24 a  |
|         | 4          | Conventional heating (CH) | 71.15 bc  | 4.2 abc  | 8.29 bcd    | 2.63 a  |
|         | 5          | Conventional heating (CH) | 69.88 c   | 3.44 c   | 8.07 d      | 2.49 a  |
|         | 6          | Conventional heating (CH) | 71.0 bc   | 3.68 bc  | 8.18 cd     | 2.56 a  |
| B       | 4          | Microwave oven (MO)  | 73.49 a         | 4.52 ab  | 9.37 a      | 2.12 a  |
|         | 5          | Microwave oven (MO)  | 73.32 a         | 4.39 abc | 9.33 a      | 2.12 a  |
|         | 6          | Microwave oven (MO)  | 73.01 ab        | 4.31 abc | 9.22 ab     | 2.02 a  |
|         | 4          | Conventional heating (CH) | 73.36 a   | 4.19 abc | 9.35 a      | 2.05 a  |
|         | 5          | Conventional heating (CH) | 73.15 ab  | 4.02 abc | 9.33 a      | 1.67 a  |
|         | 6          | Conventional heating (CH) | 72.06 abc | 3.87 abc | 9.14 abc    | 2.32 a  |
Previous studies have illustrated that popping volume of popcorn is affected by moisture content. Maximum popping volume is produced at moisture ranging from 11.0% - 15.5% and that popping volume increases with an increase in water content up to an optimal value, and then the volume decreases with any additional moisture [25, 27, 28]. However, different genotypes may have different ratios of soft and hard starch structures, which is popping volume different by this reasons [3]. From Figure 1. The expansion volume in this study was generally lower than the results by [29] this differences may be a result of the different types of popping and added oil to the samples before heating.

![Figure 1](image1.png)

**Figure 1.** Expansion volume (cm³/g) of popcorn under cooked by microwave oven (MO) and conventional heating (CH).

Microwave oven gives higher expansion volume at difference times than conventional heating. The microwave heating technology for cooking contributed to effectively significantly increase expansion volume with retain quality of popped popcorn as compared to conventional method. This result agree with [30]. In addition, statistical analysis data in Figure 1, confirmed that the interaction among samples (A and B), heating treatments (Microwave oven and conventional heating) and times (4, 5 and 6 mins) was highly significant difference in expansion volume parameter. Significantly maximum expansion volume was recorded in sample (A) under cooked by microwave oven after 4 min (16.55 cm³/g) whereas, sample (B) under cooked by conventional heating after 6 min (7.19 cm³/g) recorded lowest expansion volume. These results were close to the [31] who was reported the highest expansion volume (12.33 ml/g). And [9] have investigated that the average of expansion volume, kernels ranged between, 11.1-36.2 cm³/gm. However, these results agreed with finding of [30, 3]. The changes in expansion volume in microwave popping and conventional heating for both samples may be attributed to changes in several factors which are included moisture contents, distribution of heat among of kernels, power supply, types of samples [1, 3, 32]. However, among all factors affecting quality parameters of expansion volume, flake size and un-popped kernel, moisture contents, methods of cooking are the critical factors because they effects of the starch gelatinizes and then expands of pressure inside the kernel [28]. Figure (2) described the flake size of kernels after cooked by both methods, microwave oven and conventional heating at various periods. The flake size decreased with increased the time from 4 to 6 min of popping. Furthermore, the maximum value (2.18 cm³) of flake size was investigated in sample (A) under cooked by microwave oven after 4 min, while the minimum value (1.03 cm³) was obtained in sample (A) under conventional heating after 6 min. The flake size data was close with findings of earlier researches by [33, 1], the flake size of kernels under atmospheric and reduced pressure between 1.99-2.76 cm³ and 3.62-4.1 cm³, respectively, that is meaning surrounding pressure was a factor to give a good quality of a high flake size and lower un-popped kernel of snack.

![Figure 2](image2.png)

**Figure 2.** Flake size (cm²) of kernel of popcorn after cooking by microwave oven (MO) and conventional heating (CH).

In this study, it can be concluded that reducing the percentage of un-popped kernel is associated with increasing time cooks by both methods. The results of the analysis indicated significant variation between most of data in un-popped kernels percentage, as shown in (Figure 3). The percentage of un-popped kernel was dramatically decreased in the both methods of
microwave oven 30.67 to 1.67% and 38.67 to 1.66 %) and conventional heating (10 to 1% and 7 to 1%) with increased time from 4 to 6 min of popping. Ceylan and Karababa [9] Showed that the un-popped kernel ranged between 1.2-14.3% un-popped kernel ratios decreased with increasing kernel size when popped in a microwave oven. In addition, after cooking of popcorn using microwave oven, un-popped kernel higher in microwave treated samples. Flake size and un-popped kernel ranged between 3.7-4.6 cm³ [9].

**Figure 3.** Un-popped kernel of popcorn (%) after cooking by microwave oven (MO) and conventional heating (CH).

### 4.2. Results of minerals content

The percentage of (Fe and Zn) contents in sample A and B were obtained in this experiment (0.28, 1.04, 0.21 and 0.87%) respectively, before popping. From Table 3 it is clear that non-significant difference of minerals content in samples A and B with increased the time of popping process by both methods from 4 to 6 min. Otherwise, the minimum variation of Zn value was observed in samples B and A before and after popping (0.08 and 0.11%) by microwave oven and maximum variation was recorded in sample A and B before and after popping (0.27 and 0.25%) by conventional heating, respectively. [34] Reported that the negative correlation between popping and minerals.

**Table 3.** Minerals content (Fe and Zn%) in popped popcorn under cooked by Microwave oven (MO) and conventional heating (CH).

| Samples | Time (min) | Cooked by Microwave oven (MO) and Conventional heating (CH) | Minerals (%) |
|---------|------------|---------------------------------------------------------|--------------|
| A       | 4          | Microwave oven (MO)                                      | Fe           |
|         |            |                                                          | 0.2 a        |
|         | 5          |                                                          | 0.2 a        |
|         | 6          |                                                          | 0.19 a       |
|         | 4          | Conventional heating (CH)                                | 0.19 a       |
|         | 5          |                                                          | 0.18 a       |
|         | 6          |                                                          | 0.17 a       |
|         | 4          | Microwave oven (MO)                                      | 0.17 a       |
|         | 5          |                                                          | 0.17 a       |
|         | 6          |                                                          | 0.16 a       |
|         | 4          | Conventional heating (CH)                                | 0.16 a       |
|         | 5          |                                                          | 0.14 a       |
|         | 6          |                                                          | 0.13 a       |

### 4.3. Sensory evaluation

The visual sensory quality of the popped popcorn which includes all parameters such as tenderness, crispiness adhesive and overall acceptance based on the hedonic scales, ranging from 1-2 (dislike extremely), 3-4 (dislike slightly), 5 (neither like nor dislike), 6-7 (like slightly) and 8-10 (like extremely) were revealed in Table (4).
Table 4. Sensory evaluation of samples under cooked by microwave oven (MO) and conventional heating at different time.

| Samples | Time (min) | Cooked by                  | Tenderness (10) | Crispiness (10) | Adhesives (10) | Overall acceptance |
|---------|------------|-----------------------------|-----------------|-----------------|----------------|-------------------|
|         |            | (MO & CH)                   |                 |                 |                |                   |
| A       | 4          | Microwave oven (MO)         | 7.3 abc         | 7.67 ab         | 7.0 ab         | 7.33 a            |
|         | 5          |                             | 8.33 a          | 8.33 a          | 9.0 a          | 8.55 a            |
|         | 6          |                             | 5.33 d          | 5.0 cdef        | 6.33 bc        | 5.55 bc           |
| A       | 4          | Conventional heating (CH)   | 6.67 abcd       | 7.0 abc         | 8.0 ab         | 7.22 ab           |
|         | 5          |                             | 6.67 abcd       | 7.0 abc         | 7.0 ab         | 6.89 bc           |
|         | 6          | Microwave oven (MO)         | 3.0 e           | 3.33 f          | 3.0 d          | 3.11 e            |
| B       | 4          | Conventional heating (CH)   | 7.33 abc        | 7.0 abc         | 7.0 ab         | 7.11 ab           |
|         | 5          |                             | 6.0 bcd         | 6.33 abcd       | 5.0 cd         | 5.78 cd           |
|         | 6          |                             | 3.33 e          | 4.0 ef          | 4.0 d          | 3.78 e            |

Significant differences were investigated among most parameters for both samples under cooked by microwave and conventional heating at different time. Statistically, the highest values for each parameters of tenderness, crispiness, adhesives and overall acceptance were observed (8.33, 8.33, 9.0 and 8.55), respectively, in cooked sample (A) by microwave oven for 5 min. The data from this study indicated that the consumer extremely liked popcorn popped by microwave oven for 5 min, and disliked slightly popped popcorn under cooked by microwave oven for 6 min., which are observed the lowest values in sample B (3.0, 3.33, 3.0 and 3.11) respectively, for the above parameters, in cooked by microwave oven for 6 min. The results in this study approval with [9,31]. Hence, current study agree with researchers, Farahnaky et al. [28] have reported that a significant differences between microwave oven and conventional heating effects on popping quality.

Conclusion

The quality of popping of popcorn is identified by expansion volume un popped kernel, and flake size, as well as the preservation of chemical composition as a nutrition value and minerals contents. In this research we approved that the microwave oven better than the conventional heating regarding of expansion volume, flake size, chemical composition and minerals and sensory desire by consumers. In contrast the percentage of un-popped kernel parameter by conventional heating lower than by utilized of microwave oven. Furthermore, the time of heating, popcorn types moisture contents and different methods of heating were a crucial factors on the quality and quantity of popped popcorn.

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