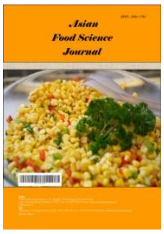

Asian Food Science Journal

21(3): 49-57, 2022; Article no.AFSJ.84981
ISSN: 2581-7752

Effects of Temperature and Variety on Rehydration Parameters and Solute Loss during Soaking of Omakwa and Abrohemaa Maize Varieties

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Authors' contributions

This work was carried out in collaboration among all authors. Author IGA managed the literature searches and conducted the experiment, collected data, analysis the data and wrote the first draft of the manuscript. Author AA conceived and designed the experiments, supervised the research and internally reviewed the manuscript; Author ABP made the final internal review and revised the final draft manuscript. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AFSJ/2022/v21i330417

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/84981

Original Research Article

Received 17 January 2022
Accepted 26 March 2022
Published 29 March 2022

ABSTRACT

This study was carried out to investigate the effects of soaking temperature and variety on the rehydration parameters and solute loss (essential minerals and vitamin C) of two maize varieties. Sun-dried kernels of the maize varieties (*Omakwa* and *Abrohemaa*) were soaked at four different water temperatures of 30°C, 40°C, 50°C and 60°C in a thermostatic water bath and the rehydration parameters determined. Temperature and variety were the two principal factors found to influence water uptake by the kernels. The highest rehydration ratio of 13.28 and 14.65 for *Omakwa* and *Abrohemaa* respectively occurred at the highest soaking temperature of 60°C. The quantitative analysis of solute loss (phosphorus, sodium, potassium and vitamin C) carried out reveals that large amounts of Potassium and vitamin C leached into the soaking water at higher water temperatures while residual amount of sodium saw an initial increase before decreasing to a low value as the temperature increases. For phosphorus, larger residual amounts were obtained at low to moderate soaking temperatures while a further increase in soaking temperature beyond 50°C resulted in a decrease. Soaking at temperatures of 40°C and 50°C were found to retain more nutrients hence moderate temperature of 40°C ≤X≤ 50°C may be considered for soaking of Omakwa and Abrohemaa maize varieties.

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Keywords: Temperature; variety; rehydration; solute loss; soaking; maize.

1. INTRODUCTION

Maize (*Zea mays* L.) belongs to the family Poaceae (Gramineae), and is one of the many cereal crops grown worldwide. Its annual production is estimated as 780 million metric tons, of which the USA, China, Brazil, and India are the major producers. Badu-Apraku, and Fakorede [1] found that maize constitute major component of the diet of Sub-Saharan Africans and also plays important role in their economies. The *Zea* genus is made up of five species: *Z. diploperennis*, *Z. luxurians*, *Z. nicaraguensis*, *Z. perennis*, and *Z. mays. Zea mays* is the only cultivated species, while others are wild grasses [2].

Maize kernels are served as food in SSA countries including Ghana, Nigeria, Sudan, Kenya, etc. The fresh kernels are eaten raw or cooked, while the mature kernels are dried and milled to produce flour of different texture which is used in various dish preparations depending on ethnic background, tradition and customs. Wet and dry milling of maize kernels are used for the production of numerous indigenous foods such as maize meals, flours, grits, starches, sweeteners, cooking oils, breads, tortillas, snacks, bioethanol and alcoholic beverages while the co-products are used as animal feed. Other studies including [3] found that when maize flour is blended with flour from other cereals enhances the nutritional and functional quality of the end product. Globally, maize has been found to have the potential for supplying the nutritional requirements of animals and humans [4].

Although, maize is a seasonal crop, it is consumed all year round. Thus, the kernels have to be dried and stored in other to make them available throughout the season. Dried kennels may be rehydrated by soaking it in water to facilitate processing operations. Generally, soaking of maize involves the immersion of kernels in water at particular temperature. This is usually followed by other processing activities depending on the expected end product. The soaking of maize has become acceptable viable process option tractable to several applications. Soaking remain one of the essential technological actions for taken out soluble compounds. It may be employed as an alternative to reduce the amount of anti-nutritional contents in foods [5,6]. Kumari [7] also found soaking to be associated with reduction in anti-nutrients levels as well as enzyme inhibitors which subsequently enhances nutritional value and digestibility. Diouf et al. [8] found that soaking in tap water for 24h provides a better bioavailability of iron and zinc.

Despite, improvement in nutritional availability and quality due to soaking, most valuable nutrients are lost through leaching during the soaking process. Loss of phytochemical, antioxidants, vitamins and minerals have been reported to be more significant than other nutrients. Other studies such as [9] have shown how cooking affects the concentrations of phenolic compounds and antioxidant activity in cultivars of cowpea.

For effective retention and utilization of both nutritive and non-nutritive value of maize for human and animal nutrition, evaluation of the effect of processing variables such as temperature on the nutritional adequacy is of paramount interest to food process engineering and technology. However, not much attention has been paid to the possible loss of the indispensable nutrients such as minerals and vitamins. Efforts by nutritionist to use maize and its derivatives to address malnutrition and other health problems will be in vain if researchers fail to include post-processing assessment of nutritional adequacy in their work. Thus, this study was designed to investigate the effects of soaking temperature and variety on the rehydration parameters and solute loss (essential minerals and vitamin C) of two maize varieties.

2. MATERIALS AND METHODS

2.1 Materials Collection

The two varieties of maize used for the study were obtained from the Crops Research Institute (CRI) of the Council for Scientific and Industrial Research (CSIR), Fumesua, Kumasi. The matured kernels were graded and only good and whole kernels were used for the study. The chemicals employed were of analytical grade and were obtained from the laboratory of the Department of Chemistry, Kwame Nkrumah University of Science and Technology, Kumasi-Ghana.

2.2 Preparation of Samples

Weighed samples were separately placed in a wire mosquito mesh bag, labelled and immersed in a portable water bath at four different temperatures of 30^{o}C, 40^{o}C, 50^{o}C, and 60^{o}C. The samples were removed at a pre-determined interval of 60 min. and were quickly blotted to remove the residual surface water with tissue paper [10] and then reweighed [11,12]. The weight gain of the samples was monitored using electronic Compact Scale, SF-400C manufactured by Yongkang Beichen Weighing Apparatus Co, Ltd until subsequent weight gain were less than 0.01 g. The samples were pulverized to form paste. The paste was then stored in a zip-lock bag and kept in the refrigerator at 4°C for the quantitative analysis.

2.3 Determination of Rehydration Parameters

The rehydration ration (RR) and coefficient of rehydration of the samples were determined using the methods described by [13] as shown in equations (1) and (2):

$$\text{Rehydration ration (RR)}=\frac{W_R}{W_D} \tag{1}$$

$$\text{Coefficient of rehydration (CR)} = \frac{W_R-W_O}{W_R}\times 100 \tag{2}$$

Where

W_R = drained weight of rehydrated material,
W_D = weight of dehydrated material
W_0 = dry matter content in the material taken for rehydration

2.4 Determination of Mineral Content

The mineral content was determined by the Method described by Obasi and Wogu [14]. The wet-digestion method was adopted to digest the samples. The digest obtained was used to evaluate the different mineral contents. De-ionized water was employed to avoid any interferences of minerals that may be present in the water. The sodium and potassium were evaluated based on the Jenway Digital Flame Photometer (PFP7 Model) adopting the filter corresponding to each mineral element. The phosphorus content was evaluated by reading the absorbance of the solution on a Spectrophotometer (Jenway Metrohm Spectronic 21D Models) at a wavelength of 470nm.

2.5 Determination of Vitamin C Content

The vitamins C content was evaluated by the method proposed by AOAC [15]. Five gram of each sample was weighed into a volumetric flask and added 10ml of 95% Ethanol to extract the vitamin C. The extract was titrated against 0.01M 2,6 -dichlorophenol solution. This was replicated to obtained average titre value. The vitamin C content was then determined by the formular:

$$\text{Vitamin C (mg/100 g)} = (\text{Titre value} \times 0.606) / \text{Weight of sample} \times 100 \tag{3}$$

3. RESULTS AND DISCUSSION

3.1 Rehydration Kinetics of Omakwa and Abrohemaa

The rehydration curves for Abrohemaa and Omakwa kernels dried in an oven are shown in Fig. 1a and 1b. It was found that the initial moisture absorption rate increased as the soaking temperature increased from 30^{o}C to 60^{o}C. Highest water absorption took place within the first 5-8hrs during which about 90% of total moisture was absorbed. This implies that faster rehydration can be obtained when the water soaking temperature is high. The study also revealed that as the water soaking temperature increased, rehydration became faster and highest moisture contents were reached at different times. Tables showing moisture contents in g water/1000g dry weight with respect to time at 30, 40, 50 and 60oC for the selected varieties are presented in Appendix A.

Fig. 1a and 1b further indicates that beyond certain time, prolonged soaking does not contribute to any further water uptake. Maharaj and Sankat [16] reported similar observation when they studied the rehydration of dried dasheen leaves. At lower temperatures Omakwa had relatively higher water uptake while Abrohemaa was found to have higher water uptake at higher temperatures. Since Abrohemaa and Omakwa were exposed to the same temperature treatments, the differences in rehydration behaviours could be possibly attributed to varietal variations. This observation is in line with the report by [17] that the internal structure of food material influenced the reconstitutability of dried food products during rehydration process. For the reason that starch molecules absorb water up to ten times their weight at high temperature [18], Abrohemaa could be said to contain more starch than Omakwa since Abrohemaa recorded significantly ($p \leq 0.05$) higher water up take at high temperatures.

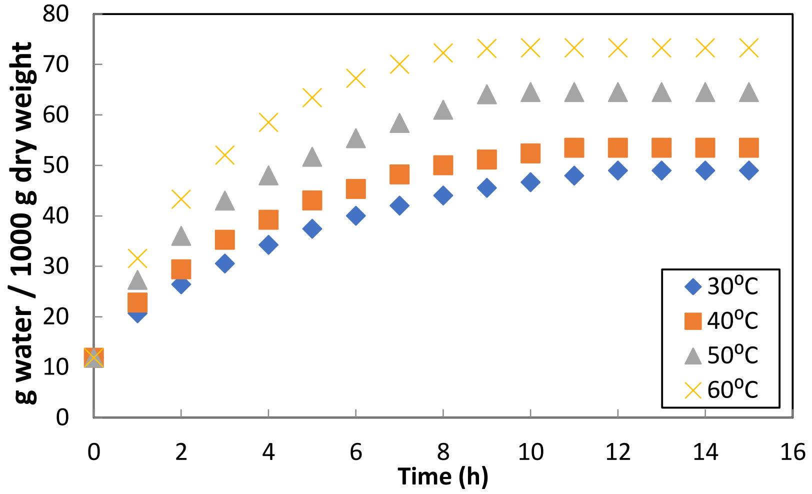

Fig. 1a. Rehydration curve of *Abrohemaa*

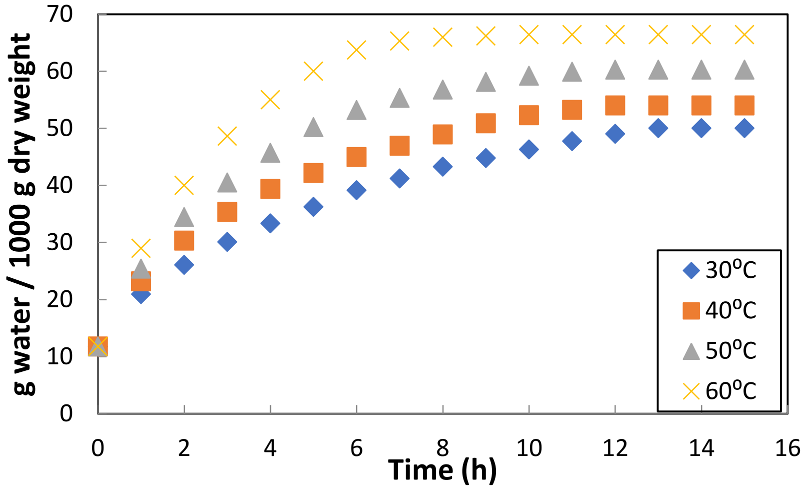

Fig. 1b. Rehydration curve of *Omankwa*

3.2 Rehydration Parameters

The values of rehydration ratio and coefficient of rehydration of rehydrated maize varieties were observed at different temperatures and the results are shown in Table 1.

The results of the study shows that rehydration ratio and coefficient of rehydration increases with increases in soaking temperature. Highest soaking water temperature of 60 °C produced an increased rehydration ratio and coefficient of rehydration. A high value of rehydration ratio signifies the quality of the dried product since the pores allow water to re-enter the cells [19]. The rehydration ratio values for Omakwa and Abrohemaa ranged from 10.00 to 13.28 and 9.79 to 14.65 respectively as shown in Table 1. The two varieties seem to have similar qualities since they have almost the same rehydration ratios. Also, high rehydration coefficients were obtained for the two samples at higher temperatures. The rapid absorption of water may be due to the increased temperature which may have possibly resulted in a more open structure in the kernels which favoured rapid rehydration. This observation is similar to that of [17] that reconstitutability of food is controlled principally by the internal structures and that the extent to which water-holding constituents like protein and starch have been destroyed during drying influences the rehydration parameters. Also, the high-water temperature could result in loss of elastic properties of cell tissues causing an opening up of the pores which invariably increased the rate of rehydration thus, dry food

Table 1. Rehydration parameters of Omakwa and Abrohemaa

	Omakwa		Abrohemaa	
T/^{0}C	**Rehydration Ratio (RR)**	**Coefficient of Rehydration (CR)**	**Rehydration Ratio (RR)**	**Coefficient of Rehydration (CR)**
30	10.00	91.1	09.79	90.9
40	10.80	91.7	10.69	91.6
50	12.05	92.6	12.90	93.1
60	13.28	93.3	14.65	93.9

material's re-constitution increased when the food has an open and porous structure. These lead to higher hydration ratio and coefficient of rehydration values at higher temperatures. This is in agreement with data shown in Table 1 where the rehydration ratio and coefficient of rehydration increased with increase in temperature. This indicates that increasing the soaking water temperature to 60^{o}C could be employed since it will result in increased moisture content of rehydrated samples.

3.3 Analysis of Solute Loss (Mineral and Vitamin C)

Processing treatment such as soaking may affect the functionality and nutritional quality of food products. The effects of variety and soaking temperature on vitamin c, potassium, sodium and phosphorus contents (mg/100 g) of two varieties of maize are provided in Tables 2 and 3. Temperature and variety variations affected the minerals and vitamin C content of the samples.

The vitamin and mineral contents of the dried and the rehydrated kernels of Abrohemaa are shown in Table 2. The residual amount of phosphorus (P) in the rehydrated kernels increased as the soaking water temperature increased. The highest residual amount of P (454mg/100g) was recorded when the temperature was 50^{o}C. The increment could possibly be attributed to increased fermentation and hydrolysis of the anti-nutrient (phytate) by phytase due to increased temperature. The Hydrolysis by phytase can convert phytate into inorganic phosphorus thereby increasing the availability of P. However, at higher temperature, the anti-nutrients (phytate) could leach out thereby decreasing their concentrations in the kernels, consequently reducing the amount of phytate available for hydrolysis. The rise in P content is in line with the report by [20], who reported an increment in the mineral content during soaking and fermentation of bambara nut. Higher hydration ratio resulting from increased temperature also played a key role in the leaching of anti-nutrients into the soaking water thereby reducing their binding effect. Therefore, maize may be soaked in water at a temperature not exceeding 50 ^{o}C in order to improve P availability. The vitamin C and potassium contents decreased as the temperature increased while Na content initially increased before decreasing. The decrease in the residual amounts of the vitamin C and minerals could be attributed to the leaching of these vitamin and minerals into the soaking water due to increased soaking temperature. The high temperature led to a decrease in the mannose content of the cell wall and caused the breakdown of the cell wall of the kernels thereby creating large surface area and an increased cell wall porosity which provided an avenue for these materials to get out of the kernel during the soaking. This observation confirms earlier reports by [21,22] that large surface area contributed to the loss of mineral content during boiling of some selected bean kernels.

The residual amount of Vitamin C, and minerals K, P and Na) in Omakwa decreased as the soaking water temperature increased from 30^{o}C to 60^{o}C. Generally, there was a decrease in the residual amounts of all the parameters studied as indicated in Table 3. However, Na recorded an

Table 2. Residual amounts of vitamin c and minerals in Abrohemaa

Temperature (^{o}C)	**Amount in mg/100 g**			
	Vitamin C	**Phosphorus (P)**	**Sodium (Na)**	**Potassium (K)**
30	20.57	418	0.4269	84.12
40	17.35	440	0.7996	71.06
50	14.07	454	0.4792	58.50
60	13.15	422	0.4199	56.01

Table 3. Residual amounts of vitamin c and minerals in Omakwa

Temperature (^{o}C)	Amount in mg/100 g			
	Vitamin C	**Phosphorus (P)**	**Sodium (Na)**	**Potassium (K)**
30	19.88	462	0.4032	88.10
40	18.74	472	0.5331	81.70
50	16.10	520	0.3724	78.68
60	13.05	481	0.3606	61.23

initial increase in the residual amount and started decreasing when the temperature had exceeded 40^{o}C. Similarly, P experienced an increase before finally decreasing to a low value of 481mg/100g at temperature ≥60^{o}C. The decrease may be traced to the high cell damage coupled with high hydration rates due to high temperature levels which caused the minerals and the vitamin to be leached out easily. Reports in literature have shown that heat has the ability to destroy vitamins. [23] documented losses of vitamins during processing operations such as soaking, blanching etc. This phenomenon was observed in this study. The study further observed that the extent of nutrient loss was different for each temperature and variety. Several changes occurred at extensive soaking temperatures. Higher Rehydration in Omakwa saw higher losses of nutrient at higher temperatures than Abrohemaa. This may be due to the differences in loss of integrity of the constituents and the damaged structure which influenced water mass flow [24]. The observed variation in hydration parameters of the two varieties could also be attributed the presence of different pore size (porosity). These Results are in agreements with the [25,26], that high temperature leads to diffusion of soluble constituents or loss of solids. Maize rehydration produces numerous changes as the increased soaking water temperature enhanced the swelling and leaching of soluble solid from dried foods. As far as possible, effort should be made to reduce vitamin and mineral losses since they are essential for bodily functions such as helping the body to fight infection, aiding wound healing. Sodium for example, is necessary for the body’s acid-base balance, absorption of glucose and for the maintenance of osmotic pressure [27].

4. CONCLUSION

The present study concluded that, the rehydration ratio and coefficient of rehydration were higher at the treatment of high soaking temperatures and that temperature and variety were the two principal factors that controlled water uptake by the kernels. Also, several changes occurred at extensive soaking temperatures and the extent of nutrient loss was different for each temperature and variety. Higher Rehydration in Omakwa saw higher losses of nutrient at higher temperature than Abrohemaa. Higher soaking temperature caused more soluble constituent such as vitamins and mineral to leach out during soaking and rehydration at the soaking temperatures of 40^{o}C and 50^{o}C were found to retain more nutrients. Moderate temperatures of 40^{o}C and 50^{o}C may be considered for rehydration of Omakwa and Abrohemaa maize varieties.

ACKNOWLEDGEMENTS

The authors express their appreciation to the Crops Research Institute (CRI) of Council for Scientific and Industrial Research at Fumesua-Kumasi, Ghana and the Agricultural and Biosystems Engineering Department of KNUST, Kumasi Ghana.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Appendix A. Tables showing moisture contents in g water/ 1000 g dry weight with respect to time at soaking temperatures of 30, 40, 50 and 60°C

	OMANKWA					***ABOROHEMAA***			
Time(h)	**30°C**	**40°C**	**50°C**	**60°C**	**Time(h)**	**30°C**	**40°C**	**50°C**	**60°C**
0	11.76	11.76	11.76	11.76	0	11.86	11.86	11.86	11.86
1	20.93	23.17	25.4	28.97	1	20.67	22.8	27.29	31.54
2	26.06	30.31	34.44	40	2	26.4	29.38	36.01	43.28
3	30.08	35.335	40.5	48.63	3	30.53	35.23	43	52.01
4	33.33	39.36	45.7	55	4	34.23	39.2	48	58.5
5	36.23	42.155	50.2	60	5	37.41	43.03	51.68	63.4
6	39.14	44.95	53.2	63.72	6	39.99	45.31	55.36	67.23
7	41.2	46.935	55.32	65.29	7	42	48.19	58.38	70.02
8	43.27	48.92	56.78	65.96	8	44.01	50	61	72.26
9	44.78	50.87	58.12	66.18	9	45.52	51.14	64.07	73.15
10	46.29	52.28	59.2	66.41	10	46.64	52.35	64.5	73.27
11	47.74	53.22	59.9	66.41	11	47.94	53.47	64.5	73.27
12	49.02	54	60.27	66.41	12	48.95	53.47	64.5	73.27
13	50.02	54	60.27	66.41	13	48.95	53.47	64.5	73.27
14	50.02	54	60.27	66.41	14	48.95	53.47	64.5	73.27
15	50.02	54	60.27	66.41	15	48.95	53.47	64.5	73.27

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