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A comparative study of the effect of microwave and conventional heating methods on proximate composition of spiced millet porridge

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Abstract

The aim of this work was to determine the effect of microwave cooking on spiced millet porridge by comparing the proximate compositions of crude protein, crude fat, moisture and ash with samples prepared using conventional cooking. The microwave cooking method involved the use of a commercial microwave oven at power levels of 360 W, 600 W and 800 W while an LPG stove was utilized for the conventional cooking. The results showed that there were slight differences in proximate compositions of crude protein, crude fat, moisture and ash between conventional cooking and microwave cooking. However, the differences were largely due to higher temperatures rather than the electromagnetic radiation that the microwave oven generates. Overall, the cooked spiced millet porridge samples recorded mean pH values of approximately 4.5 indicating the availability of requisite acidic environment for antimicrobial activity to aid reasonable preservation. Microwave oven can therefore be conveniently used to cook spiced millet porridge at a recommended power of 600 W for optimum porridge consistency.

Keywords: pearl millet, spiced millet powder, microwave heating, proximate composition

Introduction

Pearl millet (*Pennisetum glaucum*) is one variety of the millet crop that is commonly cultivated in the arid and tropical semi-arid belts of Asia and Africa [1-2]. It is known to consist of some 2.1% ash content, 2.8% of crude fiber, 7.8% of crude fat, 13.6% of crude protein and 63.2% of starch [3] in addition to a host of other vitamins and minerals. In the sub-Saharan Africa region, the crop is often processed into different cereal meals such as the spiced millet porridge (SMP), which is a staple meal and a delicacy for many people in West African countries. Generally, SMP serves as a breakfast meal and is produced from a proportionate mixture of pearl millet, cloves, ginger, dried pepper and black peppercorn milled into smooth flour to provide the required nutrients of carbohydrates, crude proteins, crude fat, crude fiber, moisture, ash and minerals [4-6] derived from the constituent crops. In most communities in that region also, it is common to find firewood, charcoal and liquefied petroleum gas (LPG) as the readily available sources of heat for conventional cooking. However, conventional cooking methods basically rely on conduction and convection mechanisms and are disadvantaged by reduced energy efficiency, longer cooking times and potential food burning especially at the base due to overheating. Therefore, with the inception of dielectric heating technology using microwaves, domestic and commercial cooking methods have been transformed extensively since then and microwave cooking is well placed to serve as the most preferred alternative to conventional cooking. Microwave heating of food occurs when part of the microwaves is absorbed by the food and dissipated as thermal energy resulting in the rise in temperature. This unique cooking method relies on volumetric system of heating [7] and its application results in uniform heating and faster rates of transfer of heat within the food which could reduce cooking times considerably while saving energy and cost.

With the rising popularity of domestic microwave cooking due to its quicker, convenient, efficient and environmentally friendly attributes, the need for research information regarding its effect on the nutrient composition of indigenous staple foods such as SMP would serve as an important consumer education since such information is readily available for several cereal and seed crop meals [8-12]. In this study, SMP meals were prepared using microwave cooking at 360 W, 600 W and 800 W power settings and the conventional cooking method with LPG stove, and the proximate compositions of crude fat, crude protein, moisture and ash as well as pH were determined and compared.

Materials and Methods

Preparation of the Spiced Millet Flour

500 g of raw pearl millet, obtained from Northern Ghana, was initially cleaned by removing impurities and then rinsed and soaked in clean water for 12 hours. The soaked millet was then rinsed again in clean water to further

remove dirt and other impurities before adding 60 g, 10 g, 5 g and 10 g of cleaned ginger, black peppercorn, dried pepper and cloves respectively for milling. The milled mixture was subsequently sieved to remove chaff to obtain the smooth spiced millet flour.

Preparation of the Spiced Millet Porridge

Conventional cooking

50 g of the spiced millet flour was first mixed with 50 ml of distilled water to form a loose paste which was then carefully poured into a pan containing 200 ml of distilled water boiling on a conventional LPG stove. The mixture was stirred and allowed to cook for 6 minutes and the final temperature of the porridge taken. Proximate analysis was subsequently carried out after the porridge was cooled to room temperature.

Microwave cooking

50 g of the spiced millet flour was transferred into a labeled beaker and 250 ml of distilled water added and stirred to form a uniform mixture. The beaker and contents were then placed in an LG commercial microwave oven (Model MS-192VUTT/02, LG, Seoul, South Korea) and allowed to cook for 6 minutes using a power setting of 360 W. The microwave oven was fitted with a rotating glass table and operated at a frequency of 2.45 GHz with intermittent heating in order to avoid overcooking. The final temperature of the porridge was immediately taken and proximate analysis subsequently carried out after the porridge had cooled to room temperature. The procedure was repeated to prepare two other portions of the porridge using oven power settings of 600 W and 800 W.

Sample Testing

Crude Fat

The crude fat contents in the raw spiced millet flour and the porridge samples prepared from conventional and microwave cooking methods were determined using the continuous solvent extraction method [13]. The determination was carried out for 6 hours using petroleum ether as the solvent and the percentage crude fat contents were subsequently calculated from the equation;

$$\% \text{ Fat} = \frac{\text{Mass of fat in sample}}{\text{Mass of dried sample}} \text{ x } 100 \tag{1}$$

Crude Protein

The percentage composition of crude protein content in the samples under test were determined from the Kjeldahl method [14]. The procedure consisted of digestion of the samples in concentrated sulphuric acid (H_2SO_4) with a catalyst to convert of all of the organic nitrogen into ammonium sulphate. The ammonia formed was distilled in an alkaline medium and collected in a solution of boric acid. A standardized solution of hydrochloric acid was then used to titrate the borate anions from which the nitrogen content, which represented the quantity of crude protein, was calculated using a conversion factor of 6.25.

Moisture Content

10 g of each sample was loaded into a weighed dry crucible and heated in an oven (Gallenkamp, Model OV 880, London, England) for 12 hours at 105°C. The dried samples were then placed in a desiccator (Glassco, Haryana, India) and allowed to cool and then reweighed. The percentage moisture content was then calculated from the expression;

$$\% \text{ Moisture} = \frac{\text{Mass loss (g)}}{\text{Original mass of sample(g)}} \text{ x } 100 \tag{2}$$

Ash Content

In order to determine the ash content, 2 g of each sample was transferred into previously dried and weighed crucibles and then heated in a Ceramic Fiber Muffle Furnace (Biobase, Shandong, China) at 600 °C for two hours to completely burn the samples into ash. The crucibles and contents were then placed in a desiccator (Glassco, Haryana, India) and allowed to cool and then reweighed to determine the mass of the ashes. The percentage ash content was then determined from the expression;

$$\% \text{ Ash} = \frac{\text{Mass of ash (g)}}{\text{Mass of sample (g)}} \text{ x } 100 \tag{3}$$

pH Measurement

The pH of all the cooked samples were determined using the Palintest Micro 800 (Palintest Ltd, Gateshead, U.K.) Multiparameter portable pH meter at room temperature. Measurements were taken in triplicates and the mean values recorded.

Statistical Analysis
Statistical analysis was carried out on all the results obtained using analysis of variance through the GenStat software (Version 11, VSN International Ltd, Hemel Hempstead, U.K., 2008) at 5 % significance level. All the tests were replicated three times and the results presented as mean ± standard deviation.

Results and Discussion
Physical Characteristics of SMP
The physical appearance of the conventionally cooked SMP samples was compared with the microwave-cooked samples on the basis of consistency and color at room temperature. Generally, all the coked samples appeared dark-grey in color, similar to the color of the uncooked samples. The consistencies of all the cooked samples were uniform, pourable and without any lumps. However, the samples cooked at microwave power of 360 W appeared light and watery while the 600 W and 800 W samples were less watery and very thick respectively.

Temperature Variation during Treatments
In order to determine the variation in temperature between the conventional and microwave cooking methods, the temperatures of the SMP meals were recorded immediately after cooking, and the mean values are depicted in Figure 1.

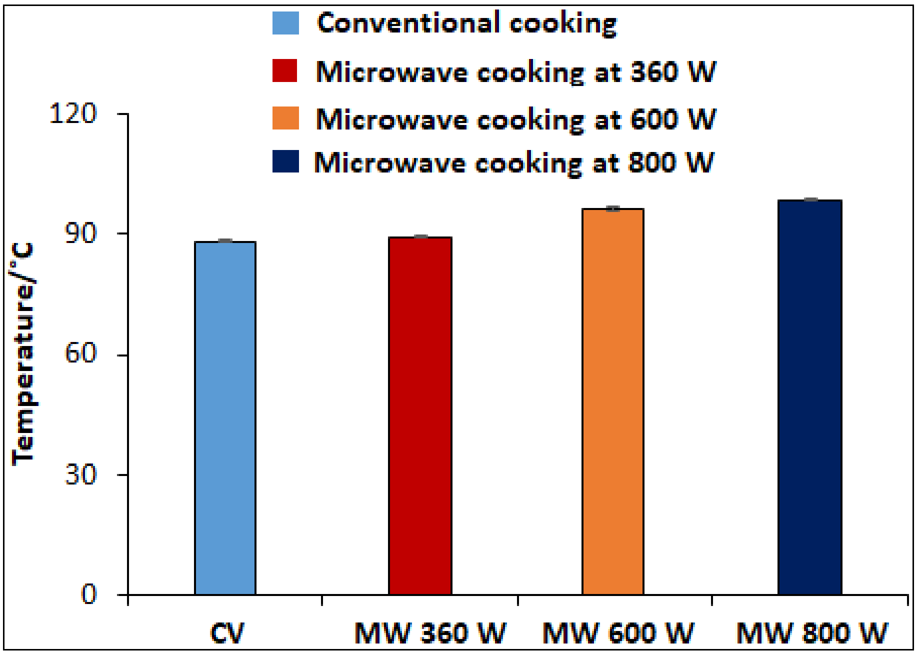

Fig 1: Variation in temperature between conventional and microwave cooking. Error bars represent standard deviation. The mean values are ± standard deviation of three replicates of each treatment. CV: Mean temperature 88.0 ± 0.20 ˚C. MW 360 W: Mean temperature 89.0 ± 0.20 ˚C. MW 600 W: Mean temperature 96.0 ± 0.32 ˚C. MW 800 W: Mean temperature 98 ± 0.35 ˚C.

The samples were all cooked for 4 minutes and as shown in Figure 1, the mean temperatures were higher in the case of the microwave cooked samples than the conventionally cooked samples. Additionally, as the microwave power increased, the mean temperatures also increased. For instance, at microwave power of 800 W, the mean temperature of the samples was about 11 % more than the mean temperature of the conventionally cooked samples. Microwave heating arises because the food substances act as dielectric materials due to the presence of moisture, salt and fat [7], and so the interaction causes polarization which leads to the dissipation of the energy in the waves as heat through absorption. The observed increase in the temperature of the samples with increase in microwave power is consistent with previous studies [15].

Proximate Composition of Crude Protein and Crude Fat
The proximate compositions (%) of crude protein and crude fat in the uncooked and cooked SMP samples are presented in Table 1. The comparisons of the values were done using least significant differences (5%) of 0.3193 and 0.1318, and coefficient of variations of 2.5 % and 3.20 % for the crude protein and crude fat respectively.

Table 1: Composition (%) of crude protein and crude fat content

Cooking Method		Composition (%)	
	Crude Protein		Ash Crude Fat
Uncooked sample	$7.65^{a} \pm 0.18$		$3.39^{a} \pm 0.02$
Conventional	$7.01^{b} \pm 0.04$		$0.91^{e} \pm 0.04$

Microwave at 360 W	6.76[b] ± 0.09		1.14[d] ± 0.08
Microwave at 600 W	6.32[c] ± 0.18		2.26[c] ± 0.18
Microwave at 800 W	5.79[d] ± 0.10		3.14[b] ± 0.06

The values stated are mean ± standard deviation of three replicates of each treatment. Means with dissimilar letters within the same column are significantly ($p<0.05$) different.

It is clear from Table 1 that initially, the uncooked spiced millet powder sample possessed significantly higher proportions of both crude protein and crude fat than the cooked samples. However, the cooking methods employed in the preparation of the porridge could mainly have accounted for their observed significantly lower values. The composition of crude protein was observed to be higher in the conventionally cooked sample than the microwave cooked samples. However, the value was not significantly different from the sample cooked with microwave at a power of 360 W. Generally, the reduction in crude protein compositions for both conventional and microwave cooking is consistent with previous works [16–17], and can be attributed to the reduced amount of quantifiable protein in the samples due to temperature-generated protein denaturation [18]. As shown in Figure 1, the relatively higher temperatures associated with microwave cooking could have led to more denaturation and therefore less measurable protein as the microwave power increased. The denaturation of a protein only causes it to lose its functional structure, however, the more temperature – resistant constituent amino acids are unaffected due to the stronger peptide bond linkages [19] and can still be nutritionally beneficial to consumers. Table 1 also depicts an increase in crude fat composition with microwave power and all the values were higher than the conventionally cooked sample, consistent with a previous work [20]. Increasing microwave power during cooking leads to higher temperatures sufficient enough to cause thermal decomposition and breaking of bonds that bind the fatty acids together [21]. The fatty acids therefore detach and open-up leading to a rise in the fat content of the samples.

Proximate Composition of Moisture and Ash

The moisture and ash compositions (%) in the uncooked and cooked SMP samples are as shown Table 2. The comparisons of the values were done at least significant differences (5%) of 0.876 and 0.0971, and coefficient of variations of 0.60 % and 12.60 % for the moisture and ash respectively.

Table 2: Composition (%) of Moisture and Ash content

Cooking Method		**Composition (%)**	
	Moisture		**Ash**
Uncooked sample	42.72[e] ± 0.29		1.27[a] ± 0.10
Conventional	88.22[a] ± 0.30		0.16[b] ± 0.00
Microwave at 360 W	86.81[b] ± 0.49		0.17[b] ± 0.00
Microwave at 600 W	84.15[c] ± 0.49		0.21[b] ± 0.02
Microwave at 800 W	78.74[d] ± 0.78		0.24[b] ± 0.00

The values stated are mean ± standard deviation of three replicates of each treatment. Means with dissimilar letters within the same column are significantly ($p<0.05$) different.

It can be deduced from Table 2 that the microwave cooked SMP retained less moisture as compared to the conventionally cooked sample and the moisture content reduced with increase in microwave cooking power, with 800 W having the highest moisture loss while 360 W produced the lowest moisture loss. Although this result is in agreement with previous studies [22–23], the higher loss of moisture can be attributed increased evaporation rates associated with the relatively higher temperatures generated when microwave cooking power is increased. Even though moisture affects consistency, appearance and savor**,** less moisture content reduces spoilage since microbial growth becomes decreased [24] and so cooked food can be kept for relatively longer periods of time. Table 2 further shows that the conventionally cooked SMP produced the lowest ash content as compared to the microwave-cooked samples while the ash content increased with increasing microwave power even though the differences were not significant. The increase in ash content with increasing microwave power was also observed in a study of the nutrient content of Bambara groundnut [23]. The ash content depends on the quantity of dry matter in the food, and since no significant differences were recorded in the treated samples, it can therefore be deduced that neither the conventional cooking nor microwave cooking affected the refinement of the SMP.

pH Analysis

In order to investigate variations in susceptibility to microbial activity, the pH measurements of the SMP samples cooked using conventional and microwave methods were taken at room temperature and compared. As shown in Figure 2, all the cooked SMP samples recorded mean pH values of approximately 4.5 which indicates that the conventional and microwave cooking methods did not affect the hydrogen ion concentration in the samples.

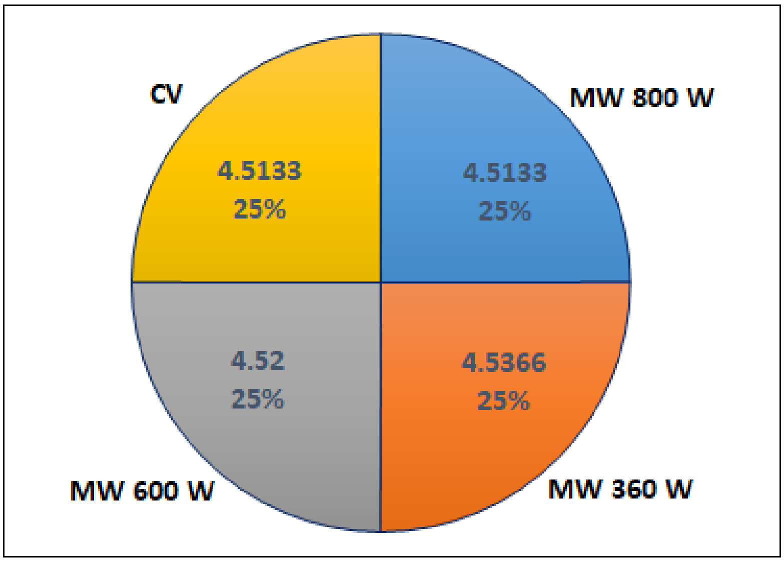

Fig 2: Mean pH values of SMP prepared from conventional cooking (CV) and microwave cooking (MW) at 360 W, 600 W and 800 W.

Additionally, pH is a determining factor for microorganism development in food, and so mean values of 4.5 provide the requisite acidic environment for antimicrobial activity. Therefore SMP conventionally cooked or microwaved could reasonably be preserved and eaten later since it would not readily go bad due to microbial activity.

Conclusion

In this study, spiced millet porridges were separately prepared using conventional cooking and also microwave cooking at power levels of 360 W, 600 W and 800 W and their proximate compositions of crude protein, crude fat, moisture and ash as well as pH were determined. The results indicated that cooking with microwave at the stated power levels produced temperatures higher than the conventional cooking which induced protein denaturation leading to reduced amounts of quantifiable protein in the samples. Additionally, the higher temperatures were sufficient enough to cause a rise in the fat content likely due thermal decomposition and breaking of bonds that bind the fatty acids together. The microwave-cooked SMP retained less moisture as compared to the conventionally cooked sample while the ash content increased with increasing microwave power even though the differences were not significant. There are therefore slight differences in proximate compositions of crude protein, crude fat, moisture and ash between conventional cooking and microwave cooking. These differences are largely due to higher temperatures rather than the electromagnetic radiation that the microwave oven generates. Overall, there was an average pH of 4.5 for all cooked samples which indicates the availability of requisite acidic environment for antimicrobial activity to aid reasonable preservation of SMP. Microwave oven can therefore be conveniently used to cook SMP at a recommended power of 600 W for optimum porridge consistency.

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References

1. Yadav OP, Rai KN. Genetic improvement of pearl millet in India. Agricultural Research,2013:2(4):275-292.
2. Rani S, Singh R, Sehrawat R, Kaur BP, Upadhyay A. Pearl millet processing: a review. Nutrition and Food Science,2018:48(1):30-44.
3. Patni D, Agrawal M. Wonder millet – pearl millet, nutrient composition and potential health benefits - a review. International Journal of Innovation Research and Review,2017:5(1):6-14.
4. Lee JG, Chae Y, Shin Y, Kim YJ. Chemical composition and antioxidant capacity of black pepper pericarp. Applied Biological Chemistry,2020:63(1):1-9.
5. Kaur K, Kaushal S, Rani R. Chemical composition, antioxidant and antifungal potential of clove (Syzygium aromaticum) essential oil, its major compound and its derivatives. Journal of Essential Oil-Bearing Plants,2019:22(5):1195-1217.
6. Ajayi OB, Akomolafe SF, Akinyemi FT. Food value of two varieties of ginger (Zingiber officinale) commonly consumed in Nigeria. ISRN Nutrition,2013:2013:1-5.
7. Hebbar HU, Rastogi NK. Microwave heating of fluid foods. Novel Thermal and Non - Thermal Technologies for Fluid Foods, 2012, 369-409.

8. Mazaheri Y, Torbati M, Azadmard-Damirchi S, Savage GP. Effect of roasting and microwave pre-treatments of Nigella sativa L. seeds on lipase activity and the quality of the oil. Food Chemistry,2019:274:480-486.
9. Hayat K, Abbas S, Hussain S, Shahzad SA, Tahir MU. Effect of microwave and conventional oven heating on phenolic constituents, fatty acids, minerals and antioxidant potential of fennel seed. Industrial Crops and Products,2019:140:1-8.
10. Khajehdizaj FP, Taghizadeh A, Nobari BB. Effect of feeding microwave irradiated sorghum grain on nutrient utilization, rumen fermentation and serum metabolites in sheep. Livestock Science,2014:167(1):161-170.
11. Songsrirote K, Naiviriya T, Rungwipoosana T, Gutrasaeng C. The study of properties and nutrient determination of hydrogel made of soybean meal (okara) using microwave-assisted heating. Materials Today Proceedings,2017:4(5):6519-6527.
12. Barba AA, Naddeo C, Caputo S, Lamberti G, d'Amore A. Microwave treatments of cereals : E ff ects on thermophysical and parenchymal - related properties. Foods,2020:9(711):1-14.
13. Min DB, Boff JM. Crude fat analysis. In Nielson S (ed), *Food analysis*: *Food science text series*. Berlin, Germany, Springer Science & Business Media, 2003, 115-120.
14. Jiang B, Tsao R, Li Y, Miao M. Food safety: Food analysis technologies/techniques. In Van Alfen NK (ed.), Encyclopedia of agriculture and food systems. Amsterdam, Netherlands, Elsevier Inc, 2014, 273-288.
15. Zhao P, Liu C, Qu W, He Z, Gao J *et al.* Effect of temperature and microwave power levels on microwave drying kinetics of zhaotong lignite. Processes,2019:7(74):1-18.
16. Rashid MA, Saifullah M, Habib MA, Hussain I, Sattar MA. The effect of different cooking methods on nutrient content of selected Bangladeshi fish. International Journal of Advanced Research in Chemical Science,2016:3(8):9-14.
17. Rashid MA, Hussain MI, Rahman A, Khatun MK, Sattar MA. The effect of microwave cooking on nutrient value of fresh vegetables. International Journal of Nutrition and Food Sciences,2016:5(4):273-277.
18. van Dijk E, Hoogeveen A, Abeln S. The hydrophobic temperature dependence of amino acids directly calculated from protein structures. PLoS Computational Biology,2015:11(5):1-17.
19. Genchi G. An overview on d-amino acids. Amino Acids,2017:49(9):1521-1533.
20. Chauhan V, Saxena S. The study of microwave heating on proximate composition in fish fillets and balls. The Pharma Innovation Journal,2017:6(9):117-122.
21. Baig A, Zubair M, Sumrra SH, Nazar MF, Zafar MN *et al.* Heating effect on quality characteristics of mixed canola cooking oils. BMC Chemistry,2022:16(3):1-11.
22. Azimi-Nejadian H, Hoseini SS. Study the effect of microwave power and slices thickness on drying characteristics of potato, Heat and Mass Transfer,2019:55(10):2921-2930.
23. Oyeyinka SA, Ajisafe AO, Akintayo OA, Iyiola OA, Oyeyinka AT *et al*. Effect of microwave treatment on cooking time, colour, sensory and nutritional properties of Bambara groundnut (Vigna subterranea). Croatian Journal of Food Technology, Biotechnology and Nutrition,2020:15(1-2):11-16.
24. Vera ZM, Dutta B, Mercer DG, MacLean HL, Touchie MF. Assessment of moisture content measurement methods of dried food products in small-scale operations in developing countries: A review. Trends in Food Science and Technology,2018:88:484-496.