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Chemical Evaluation of the Effect of Roasting on the Nutritive Value of Maize (*Zea mays*, Linn.)

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ABSTRACT

This study reports on the effects of roasting on the chemical composition of maize (Zea mays). *Proximate analysis showed no significant difference* ($p > 0.05$) *between raw and roasted maize in ether extract, crude protein, crude fibre, ash and carbohydrate content; except moisture content* ($p < 0.05$), *which showed a 42·3% decrease. Elemental composition analysis showed decreases of potassium (13·8%) and calcium (41·1%). Significant differences* ($p < 0.05$) *were observed for vitamins* B_1, B_2 *and C contents with 26·8%, 32·4% and 35·1% destruction, respectively. Amino acid analysis showed losses for lysine (26·7%),* iso-*leucine (20·8%) and leucine (23·4%).*

There was significant ($p < 0.05$) *variation in phytic acid, oxalic acid, tannin and hydrocyanic acid with reductions of 15·4%, 6·02%, 51·3% and 34·6% respectively.*

The effect of these changes on the nutritive value of roasted maize is discussed.

INTRODUCTION

Dry heat treatment applied for the purposes of processing, cooking and preserving food is known to have mixed effects on its nutritive value. Heat is known to improve the availability of some nutrients—to inactivate enzymes that speed up nutrient damage, destroy undesirable micro-organisms and food contaminants and favourably change the physical

attributes of food such as colour, texture and flavour. For example, roasting has been shown to liberate niacin from niacytin in maize, pears and rice (Rajalakshmi *et al.*, 1964) and the baking of maize into chappaties increased the free nicotinic acid (Bender, 1966). Undesirable changes do occur concurrently with these desirable modifications. One such change of great concern is the loss of nutrients. The nutritional losses that occur in food processing have been reviewed by Bender (1966), Cain (1967) and Lachance *et al.* (1973). Most of the available information on the effect of cooking on the nutritive value of foods in Nigeria has been in connection with a wet heat method of cooking (Oke, 1966; Akinrele & Basir, 1967; Malik, 1967; Eka & Edijala, 1972; Ogunmodede, 1972; Abaelu, 1973; Okoh & Eka, 1978; Osinubi & Eka, 1981). However, studies on the effect of roasting (dry cooking) on the nutritive value of foodstuffs in Nigeria are scanty or unavailable. Maize is one of the foodstuffs widely eaten roasted by a great number of Nigerians of both the low- and high-income groups. There are no reported studies on the effect of roasting on the nutritive value of maize. The present series of investigations was carried out to evaluate, by chemical analyses, the effect of roasting on the nutritive value of maize.

EXPERIMENTAL

Collection and treatment of samples for analysis

Samples of maize (*Zea mays* Linn.) of the white variety were bought from the Watt and Akim markets at Calabar, Cross River State of Nigeria, between June and July of 1981. The samples were pooled, then divided into two portions. One of the portions was roasted and milled whilst the other was milled raw. The maize sample was roasted in the laboratory in an aluminium frying pan using a 100W electric stove (Sans Ming Taiwan) as the heat source. Preliminary roasting trials were made and the roasting time and temperature standardized. In the roasting process the pan was placed on the stove and allowed to warm to a temperature of between 50 and 60 °C. Next, 100 g of maize samples were added at each time and heating continued with stirring until the temperature reached between 120 and 130 °C. Heating was then stopped and the grains were stirred until the temperature dropped to between 70 and 80 °C. Under this treatment, the grain was roasted to the desired consistency. The time required to roast

each 100-g sample ranged from 14 to 17 min. The roasting conditions were designed to emulate, as far as possible, the method of roasting maize practised in rural areas.

The raw and roasted maize samples were ground separately into fine powder in a steel-bladed grinding mill (National, Model MK308, Japan). Each sample was ground to produce a very fine powder, to pass through a 30 mesh sieve (AOAC, 1975). The samples were stored in airtight bottles from which the required quantities were removed for chemical determinations.

Analysis of samples

The methods of sample treatment and analysis were the standard methods recommended by the Association of Official Analytical Chemists (AOAC, 1975) and by Joslyn (1970).

The ash was determined by incineration of known weights of the samples in a muffle furnace at 550 °C until ash was obtained. The lipid composition was determined by exhaustively extracting a known weight of sample with petroleum ether (boiling point, 40–60 °C) using Soxhlet apparatus. Protein (N × 6·25) was determined by the macro-Kjeldahl method. The carbohydrate content was obtained by the difference method; that is, by subtracting the total crude protein and crude lipid from the organic matter. Crude fibre was determined by the acid and alkaline digestion methods described by Joslyn (1970) and the AOAC (1975).

The elemental composition was also determined using the methods of the AOAC (1975). Sodium and potassium were determined by flame photometric methods, calcium, magnesium, zinc, iron and copper using an absorption spectrophotometer and phosphorus by colorimetric methods using ammonium molybdate. The amino acid contents of the samples were determined using a Beckman automatic amino acid analyser (Spackman *et al.*, 1958).

The vitamins were determined using the methods of the Association of Vitamin Chemists (AOVC) (1966). Carotene was determined colorimetrically at 455 nm. Thiamine was estimated as thiochrome by the fluorometric method, riboflavin was also estimated fluorometrically, using a Locarte fluorimeter. Vitamin C (ascorbic acid) was estimated by the *N*-bromosuccinimide method described by Evered (1960), and total ascorbic acid by the 2,4-dinitrophenyl-hydrazine method (Scharffert &

TABLE 1
Proximate Composition of Raw and Roasted Maize and Their Physiological Fuel Values

	*Wet weight g/100 g dry food sample**						*PFV†*
	Moisture	*Ash*	*Pet. ether extract*	*Crude protein*	*Crude fibre*	*Carbohydrate*	*(calories)*
Raw maize	12·54 ± 1·74	1·39 ± 0·08	4·34 ± 0·27	9·10 ± 0·20	1·42 ± 0·06	72·63 ± 2·00	366
Roasted maize	7·24 ± 1·11	1·35 ± 0·14	4·60 ± 0·18	9·22 ± 0·20	1·36 ± 0·04	76·23 ± 4·10	383
Per cent loss (−) or gain (+) on roasting	−42·26	−2·88	+5·99	+1·32	−4·23	+4·96	+17

* Mean of three determinations ± standard deviation.
† PFV = Physiological Fuel Value.

TABLE 2
Elemental Composition of Raw and Roasted Maize Samples

	*mg/100 g dry food sample**								*Ca:P*
	K	*Na*	*Ca*	*Mg*	*Zn*	*Cu*	*Fe*	*P**	*ratio*
Raw maize	363	4	85	119	7·50	0·08	1·50	317	1:3·73
Roasted maize	312	4	50	121	7·50	0·08	1·45	330	1:6·60
Per cent loss (−) or gain (+) on roasting	−13·8	0	−41·1	+1·68	0·00	0·00	−3·30	+4·29	—

* Mean of three determinations.

TABLE 3
Vitamin Contents of Raw and Roasted Maize

	*mg/100 g dry sample**					
	Thiamine (B_1)	*Riboflavin* (B_2)	*Ascorbic acid (C)*	*Total vitamin C*	*Carotene*	*Ascorbic acid: Total Vit. C ratio*
Raw maize	0·41 ± 0·03	0·34 ± 0·02	9·13 ± 0·61	15·9 ± 0·70	4·25 ± 1·06	0·57
Roasted maize	0·30 ± 0·01	0·23 ± 0·03	5·93 ± 0·50	11·6 ± 1·44	3·20 ± 1·13	0·37
Per cent loss (−) or gain (+) on roasting	−26·8	−32·4	−35·1	−27·3	−24·7	—

* Mean of three determinations ± standard deviation.

Kingsley, 1955). Oxalate was determined by the method of Dye (1956) as modified by Oke (1965). Hydrocyanic acid content was determined by the alkaline titration method (AOAC, 1975). Phytic acid was estimated by a photometric method adapted from the method of McCance & Widdowson (1935). The tannin was determined by the vanillin–HCl reagent method (Joslyn, 1970; Burns, 1971).

RESULTS

The results are shown in Tables 1 to 8. The results of the proximate composition of the maize samples are shown in Table 1. The results show

TABLE 4
Phytic Acid Content of Raw and Roasted Maize

	*mg/100 g dry sample**		*Per cent phosphorus as phytin*
	Total phosphorus	*Phytic acid phosphorus*	
Raw maize	317	146 ± 9·44	46·1
Roasted maize	331	123 ± 8·20	37·5
Per cent loss (−) or gain (+) on roasting	+4·29	−15·38	—

* Mean of three determinations ± standard deviation.

TABLE 5
Oxalic Acid Content of Raw and Roasted Maize

	*g/100 g dry food sample**			*Per cent total oxalate as soluble oxalate*	*Calcium: Soluble oxalate ratio†*
	Total calcium	*Total oxalate*	*Soluble oxalate*		
Raw maize	0·09	2·41 ± 0·01	0·55 ± 0·05	22·7	1:2·78
Roasted maize	0·05	2·27 + 0·09	0·60 + 0·06	25·3	1:5·46
Per cent loss (−) or gain (+) on roasting	−41·12	+6·02	+8·88	—	—

* Mean of three determinations ± standard deviation.
† The calcium: soluble oxalate ratio was calculated assuming that 40 g combines with 88 g oxalate (molar reaction).

TABLE 6
Tannin and Hydrocyanic Acid Content of Roasted and Raw Maize Samples

	*mg/100 g dry sample**	
	Tannin	*Hydrocyanic acid*
Raw maize	30·9 ± 2·02	2·20 ± 0·18
Roasted maize	15·1 ± 2·52	1·44 ± 0·16
Per cent loss (−) or gain (+) on roasting	−51·3	−34·6

* Mean of three determinations ± standard deviation.

TABLE 7
Amino Acid Composition of Raw and Roasted Maize Samples

	g amino acid/16 g N		*Per cent loss (−) or gain (+) on roasting*
	Raw maize	*Roasted maize*	
Lysine	3·00	2·20	−26·7
Tryptophan	—	—	—
Iso-leucine	4·00	3·17	−20·8
Leucine	12·5	9·58	−23·4
Methionine	3·00	4·08	+36·0
Phenylalanine	—	—	—
Threonine	3·60	2·93	−18·6
Valine	6·67	5·29	−20·7
Cystine ($\frac{1}{2}$)	1·50	1·12	−25·3
Tyrosine	5·00	4·07	−18·6
Aspartic acid	6·41	5·43	−15·3
Serine	4·90	4·05	−17·4
Glutamic acid	18·9	16·2	−14·2
Proline	8·83	10·2	+15·2
Glycine	3·90	3·09	−20·8
Alanine	7·69	5·96	−22·5
Histidine	—	—	—
Arginine	4·70	4·73	+0·64
Protein, g/100 g food	9·10	9·22	+1·32

— = Not determined.

no significant ($p > 0{\cdot}05$) changes in the ash, crude fat, crude protein, crude fibre and carbohydrate contents of the maize samples with roasting.

Table 2 shows the results of the mineral element composition. There was a reduction in potassium (13·8 %) and calcium (41·1 %) contents with roasting whilst other mineral elements, such as sodium, magnesium, zinc, copper, iron and phosphorus, were not much affected by roasting.

Table 3 shows the vitamin content of both raw and roasted maize. There were significant reductions in the levels of carotene (24·7 %), thiamine (26·8 %), riboflavin (32·4 %), ascorbic acid (35·1 %) and total ascorbic acid (27·3 %) with roasting.

Tables 4, 5 and 6 show the levels of phytic acid, oxalic acid, tannin and hydrocyanic acids in both raw and roasted maize. There was a significant reduction in the levels of phytic acid (15·4 %), oxalic acid (6·02), tannin (51·3 %) and hydrocyanic acid (34·6 %).

Table 7 shows the amino acid composition of the raw and roasted maize samples. A decrease in the levels of most of the amino acids was observed but an increase was shown for proline (15 %) and methionine (36 %). Of the essential amino acids, a decrease in level was observed for

TABLE 8

Essential Amino Acid Composition of Raw and Roasted Maize (Comparison with FAO/WHO Provisional Pattern and Egg)

	g/16 g N			*Egg*†
	Raw maize	*Roasted maize*	*FAO/WHO**	
Iso-leucine	4·00	3·17	4·00	6·60
Leucine	12·5	9·58	7·04	8·80
Lysine	3·00	2·20	5·44	6·60
Methionine + Cysteine	4·50	5·22	3·52	5·40
Phenylalanine + Tyrosine	5·50	4·07	6·08	10·8
Threonine	3·60	2·9	4·00	5·00
Tryptophan	—	—	0·96	1·70
Valine	6·67	5·29	4·96	7·40
Amino acid index**	45·5	33·3	82·4	100

* FAO/WHO (1973).

† Values taken from Food and Nutrition Board (1963).

** Amino acid index was calculated using lysine compared with its value in egg.

— = Not determined.

lysine (26·7%). Tryptophan, histidine and phenylalanine were not determined in either the raw or the roasted maize samples.

Table 8 shows the essential amino acid composition of the maize samples compared with the FAO/WHO (1973) provisional pattern and with that of the standard protein of whole hen's egg.

DISCUSSION

From the results of the investigations described above it is clear that there were sizeable drops in the levels of nutrients in maize as a result of roasting. The varieties of traditional cooking methods used in Nigeria have been recognized as important factors contributing to the malnutrition problems in the country (FAO/UNICEF, 1962). One of the most pressing nutritional problems facing the Nigerian Government and, indeed, the governments of several Third World countries is how to be self-sufficient in food production. Most of the studies so far carried out show inadequacies in quantity and quality of foods, exemplified by widespread malnutrition (Bassir, 1953; Ekpo, 1970; Osifo, 1977). The people most affected are the pre-school age children and pregnant and lactating women (ICNND, 1965; Nnanyelugo, 1980). Maize is not a good source of good quality protein since it is deficient in tryptophan and lysine. Roasting causes a further reduction in lysine. There is therefore a need to supplement meals of roasted maize with other richer sources of nutrients such as fish, milk, beans (particularly soya beans), eggs, green leafy vegetables and meat. Studies have established that there are lesser known rich sources of proteins such as crayfish, periwinkle and snails (Akinrele & Edwards, 1971; Umoh & Bassir, 1977; Eka, 1978; Ifon, 1980; Umoh *et al.*, 1980). These sources of protein, which are cheap and widely available in the maize-eating parts of Nigeria, should therefore be recommended.

There may be a need to look into the traditional roasting conditions and techniques with a view to improving them so that their adverse effects on the nutritive value of foods may be considerably minimized. This is essential since many foods in Nigeria, such as yam, plantain, cocoyam, garri, groundnuts, melon seeds, African bread fruit seeds, meat, African pear fruits and others, are cooked by roasting. The effects of roasting on the nutritive value of these foodstuffs have yet to be established.

The amino acid profile of a protein alone may not be the most ideal

measure of its nutritional quality. However, in chemical assessment, the amino acid index is a fair estimation of protein quality. This measure has been found to correlate well with such biological indices as NPU. The purpose of this study was to quantify the amino acid losses due to roasting.

The increase of nitrogen (1·3%) reported on roasting was not significant and could be explained as being due to a decrease in moisture content with a concomitant increase in solid matter, including protein (nitrogen). When corrections for moisture content were made it was found that there was a loss of nitrogen. Some loss of amine nitrogen and probably rarely amide nitrogen, as NH_3, was expected and this might be anticipated to cause a slight increase in amino acid content per unit of total nitrogen. However, the results showed that, apart from methionine, proline and arginine, all the other amino acids exhibited considerable decreases on roasting of maize. The increase of methionine was more than could be explained.

The decrease in 'non-paraffinic' amino acids on roasting could be due to thermal destruction. However, the losses in the unreactive paraffin side chain amino acids, leucine, *iso*-leucine and valine, is not clear. The temperature range and time of heating were not considered high enough to have accounted for such considerable losses. However, in the case of *iso*-leucine, it is possible some could have been lost through the thermal conversion to allo-*iso*-leucine (Bjarnason & Carpenter, 1970).

Histidine and phenylalanine were not determined (Table 7). The loss of thiamine, ascorbate and riboflavin on heating was expected (Table 3). However, the loss of riboflavin was slightly higher than expected since riboflavin is less heat labile than thiamine. The loss in riboflavin could be attributed to heat alone since other environmental conditions were similar for the raw and roasted maize samples.

Tannin and hydrocyanic acid were found to have decreased on roasting by 51·3% and 34·6%, respectively (Table 6). This could be an important observation since tannins reduce the bioavailability of proteins and the protein values of food (Ford & Hewitt, 1979). Hydrocyanic acid is toxic to animals and is implicated in chronic degenerative neuropathy (Osuntokun *et al.*, 1969). However, since even the initial amount present is low (tannins, 30·9 mg%; hydrocyanic acid, 2·2 mg%), tannins and cyanogenic glucosides may not be considered a practical problem with maize in the human diet.

A study on the effect of roasting on the nutritional quality of maize (as

measured by the effect on the biological performance of rats) has already been carried out and will soon be reported. However, it is worth mentioning that chemical studies are in good agreement with biological studies; that is, roasting considerably reduces the nutritive value of maize.

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