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Compositional and Protein Digestibility Changes in Maize (*Z. mays*) and Cowpea (*V. unguiculata*) after Storage at Ambient Conditions

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ABSTRACT

Grains of maize and cowpea were stored in cloth bags for 7 months under ambient conditions of temperature (18–35·6°C) and relative humidity (30–97%). There were no significant changes in the total soluble sugars, free amino nitrogen, titratable acidity or pH of the grains ($P > 0{\cdot}05$). There was a decrease in the in-vitro protein digestibility of corn grains and an increase in the protein digestibility of cowpea grains ($P < 0{\cdot}05$). Cooking of stored corn grains resulted in an increase in the true digestibility above the level for the fresh sample ($P < 0{\cdot}05$). Depreciation in the protein digestibility of grains during storage may be relevant to only the raw samples.

INTRODUCTION

Maize (*Zea mays*) and cowpea (*Vigna unguiculata*) are the most widely consumed cereal and legume grains in the diets of Nigerians. Storage of the two food grains under different conditions is attended by changes in their chemical compositions (Daftary *et al.*, 1970; Van Twisk, 1970; Onigbinde & Akinyele, 1988) and depreciation in their protein quality (Henry *et al.*, 1939; Sahn & Nadezhnova, 1971; Molina *et al.*, 1975). The growing demand for high quality plant protein calls for increasing understanding of the extent of storage losses under different climatic conditions; and the prevention of such

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changes during household processings. The aim of this study was therefore to estimate changes in some biochemical parameters and the effect of boiling on any decrease in protein digestibility.

MATERIALS AND METHODS

Fresh grains of maize and cowpea purchased locally were sun-dried to 12–14% moisture and packaged in lots of about 2·0 kg each. Three bags of each crop were placed on open shelves for 7 months during which the ambient temperature and relative humidity fluctuated from 18–35·6°C and 30–97%, respectively.

Chemical analysis

The grains in each bag were milled and sieved to 0·5 mm particle sizes. The flours were analysed in triplicate before and after storage.

The pH, titratable acidity, free amino nitrogen, total soluble sugars and in-vitro digestibility were estimated as earlier described in detail (Onigbinde & Akinyele, 1988).

The pH was estimated on 1/10 (w/v) suspension of flour in distilled water. The titratable acidity was determined as the amount of alkali (0·01N sodium hydroxide) required to neutralise the filtrate of a 2/40 (w/v) suspension of sample in distilled water. The free amino nitrogen was by the formol titration method (Harrow *et al.*, 1955) and total soluble sugars was quantified by a combination of the extraction method of Southgate (1976) and the phenol–sulphuric acid method of Dubois *et al.* (1956) using sucrose as standard.

The in-vitro protein digestibility was determined by the multienzyme technique of Satterlee *et al.* (1979). The results are presented in Table 1.

In-vitro protein digestibility

A nitrogen-free diet (basal), a control diet (ANRC, Casein) and four test diets, each compounded to contain about 10% protein (Table 2), were separately administered to a group of six male rats (Wistar strain). The rats were singly housed in metal cages with facilities for urine and faecal collection. The animals were fed *ad libitum*. The first 4 days were regarded as an acclimitisation period at the end of which the rats weighed between 46 and 50 g. The food intake, and faecal and urine (basal diet only) outputs were recorded for 7 days following acclimatisation. The faeces were pooled together for each animal, dried at 60°C for 24 h and milled to powder. The

TABLE 1
Protein Digestibility, pH, Titratable Acidity, Total Soluble Sugars and Free Amino Nitrogen of Maize and Cowpea Stored under Ambient Conditions[a]

Samples		*Protein digestibility (%)*	*pH*	*Soluble sugars (%)*	*Free amino nitrogen (g%)*	*Titratable acidity*[b]
Yellow Maize	Fresh	76 ± 4	6·3 ± 0·4	3·6 ± 0·4	3·8 ± 0·5	3·6 ± 0·1
	Stored	73 ± 0	6·3 ± 0·0	3·4 ± 0·2	3·5 ± 0·3	3·7 ± 0·3
White Maize	Fresh	74 ± 4	6·4 ± 0·2	3·8 ± 0·5	3·9 ± 0·3	3·2 ± 0·4
	Stored	72 ± 3	6·4 ± 0·1	3·9 ± 0·1	3·7 ± 0·2	3·4 ± 0·2
Brown Cowpea	Fresh	75 ± 7	6·4 ± 0·4	8·8 ± 1·0	1·7 ± 0·1	1·5 ± 0·1
	Stored	83 ± 3	6·4 ± 0·2	8·2 ± 0·3	1·8 ± 0·1	1·4 ± 0·2
White Cowpea	Fresh	80 ± 7	6·4 ± 0·2	7·9 ± 0·6	1·7 ± 0·2	1·5 ± 0·1
	Stored	85 ± 1	6·4 ± 0·1	7·6 ± 0·2	1·7 ± 0·0	1·4 ± 0·2

[a] Mean ± SD.
[b] mg NaOH/100 g.

total nitrogen was estimated by the macroKjeldahl procedure (AOAC, 1980) and the apparent and true digestibility were calculated as described by Mitchell (1923).

Cooking

Cooking was carried out by boiling the grains in water until they were soft to touch. The cooked grains were blended into smooth paste and dried at 60°C (Gallenkhamp air-oven). The cake was milled and sieved to 0·5 mm size.

TABLE 2
Composition of Diets used for the In-Vivo (Rat) Assay

Ingredients	*Basal diet*	*Control diet*	*Fresh Maize*		*Stored Maize*	
			Raw	*Cooked*	*Raw*	*Cooked*
Casein[a]		100				
Test diets			825	750	825	760
Cassava starch[b]	840	740	15	90	15	80
Glucose	10	10	10	10	10	10
Corn oil	100	100	100	100	100	100
Mineral mixture[c]	40	40	40	40	40	40
Vitamin mixture[d]	10	10	10	10	10	10

[a] ANRC Casein (Humko Sheffield Chem. Co., USA).
[b] Peeled washed, fermented, dried and sieved (40 mesh).
[c] Supplied by BDH Chem. Ltd, UK.
[d] Supplied by ICN. Nutritional Biochemicals, Ohio, USA.

Statistics

The significance of the variations between replicates (or animals) and between food samples was tested by the analysis of variance (Steel & Torrie, 1960).

RESULTS

The results (Table 1) showed that there was 6·3 to 10·7% increase in the protein digestibility and 1·9% increase in free amino nitrogen contents of the brown cowpea grains. The titratable acidity decreased by 6·7% and soluble sugars by 3·8 to 6·8%, respectively. Comparison of the fresh and stored maize grains showed that the protein digestibility decreased by 2·7 to 4·9%, soluble sugars by 5·6% (in yellow maize) and the free amino nitrogen decreased by 5·1 to 7·9%. There was an increase of 2·8 to 6·3% in the titratable acidity and 2·6% increase in the total soluble sugar content of the white maize grains. All the changes were not statistically significant ($P > 0{\cdot}05$). There were no changes in the pH of the two food grains.

Result of the in-vivo assay (Table 3) showed that the stored maize had a higher true digestibility (96%) than the fresh maize (92·1%) after cooking. Raw stored maize had a higher true digestibility (96·1%) than raw fresh maize (94·5%). The effects of both cooking and storage on the protein digestibility were insignificant ($P > 0{\cdot}05$).

Table 4 shows the effect of boiling on the in-vitro protein digestibility (Satterlee *et al.*, 1979) of maize and cowpea grains stored at 55°C for 7 months as described previously (Onigbinde & Akinyele, 1988). The decreases in protein digestibility were 11·8% and 8·4% for yellow and white maize and 5·3 and 6·3% for brown and white cowpea, respectively. The protein digestibility increased after boiling by 2·6, 10·8, 2·7 and 0·6% in the

TABLE 3
In-Vivo Protein Digestibility of maize (*Z. mays*) as Affected by Storage and Cooking[a]

Diets		*Food intake (% N)*	*Faecal excretion (% N)*	*Apparent digestibility (%)*	*True digestibility (%)*
Fresh maize	Raw	0·48	0·04	90·9	94·5
	Cooked	0·59	0·06	89·1	92·1
Stored maize	Raw	0·58	0·04	93·0	96·1
	Cooked	0·54	0·04	92·5	96·0

[a] Mean ± SD for six rats on each diet.

TABLE 4
In-Vitro Estimated Effects if Cooking on the Protein Digestibility (%) of Fresh and Heat Damaged Grains of Maize (*Z. mays*) and Cowpea (*V. unguiculata*)

Samples	*Fresh*		*Stored*[a]	
	Raw	*Cooked*	*Raw*	*Cooked*
Yellow maize	76 ± 4	78 ± 3	67 ± 5	72 ± 1
White maize	74 ± 4	82 ± 3	68 ± 6	78 ± 4
Brown Cowpea	75 ± 7	77 ± 5	71 ± 4	77 ± 4
White Cowpea	80 ± 7	80 ± 4	75 ± 5	80 ± 3

[a] Seven months at 55°C (Onigbinde & Akinyele, 1988).

fresh grains and 7·5, 11·7, 8·5 and 6·7% after storage of yellow maize, white maize, brown and white cowpea respectively. The residual losses in protein digestibility were 7·7 and 4·9, for yellow and white maize, respectively ($P > 0{\cdot}05$).

DISCUSSION

The changes in the biochemical composition of the grains, although statistically insignificant ($P > 0{\cdot}05$), agree with the reported changes in pH (Mills *et al.*, 1978), free amino nitrogen (Jones & Gersdoff, 1941), total soluble sugars (Onayemi *et al.*, 1986) and protein quality (Jones & Gersdoff, 1941; Sowunmi, 1981) during storage of maize, cowpea and some other food grains. The authors associated the changes in the chemical composition with structural changes, activities of endogenous enzymes and microbial activities which resulted from fungal and/or bacterial infestation. These reasons might also be valid for the result of this study since the grains were allowed to exchange heat, moisture and oxygen with the environment. The increase in the protein digestibility of all the samples, after cooking, probably resulted from the tenderising effect of boiling, the gelatinisation of the starch and denaturation of the protein component, all of which enhanced the accessibility of the linkages to enzyme hydrolysis. Of greater importance, however, is the observation that the ambient condition was of insignificant consequence to the biochemical composition of the grains and that boiling is sufficient to remove any inhibition of protein digestibility. The persistence of reduction in protein digestibility of the severely heated sample, after boiling, suggests that storage decrease in protein digestibility might be caused by weak structural changes, compatible with storage under mild temperature condition, followed by strong covalent linkages between and within the polymeric constituents, which are irreversible by conventional boiling. Thus, the decrease in protein quality of food grains stored under ambient conditions reported by previous authors, may be relevant to raw grains only.

The difference in the storage changes in the protein digestibility of maize and cowpea might be of interest in the production of heat-treated mixes of the two food grains.

REFERENCES

AOAC (1980). *Official Methods of Analysis* (13th edn). Association of Official Analytical Chemists, Washington, DC.

Daftary, R. D., Pomeranz, Y. & Saner, D. B. (1970). Changes in wheat flour damaged by mould during storage. Effects on lipid, lipoprotein, and protein. *J. Agric. Food Chem.*, **18**, 613–16.

Dubois, M., Gilles, K. A., Hamilton, J. K., Rebers, P. A. & Smith, F. (1956). Colorimetric method for determination of sugars and related substances. *Anal. Chem.*, **26**, 350–6.

Harrow, B., Borek, E., Mazuz, A., Stone, G. C. H. & Wagreich, H. (1955). *Laboratory Manual of Biochemistry (4th edn). W. Saunders, Philadelphia, PA, p.* 56.

Henry, K. M., Honston, J., Kon, S. K. & Osborne, L. W. (1939). The effect of commercial drying and evaporation on the nutritive properties of milk. *J. Dairy Res.*, **10**, 272–6.

Jones, D. B. & Gersdoff, C. E. F. (1941). The effect of storage on the protein of wheat, white flour and whole wheatflour. *Cereal Chem.*, **18**, 417–34.

Mills, J. T., Sinha, R. N. & Wallace, H. A. H. (1978). Assessment of quality criteria of stored rapeseed: A multivariant study. *J. Stored Product Res.*, **14**, 121–33.

Mitchell, H. H. (1923). A method of determining the biological value of proteins. *J. Biol. Chem.*, **58**, 873–922.

Molina, M. R., De La Fuente, G. & Bressani, R. (1975). Interrelationships between storage, soaking time, cooking time, nutritive value, and other characteristics of the black bean (*Phaseolus vulgaris*). *J. Food Sci.*, **540**, 587–90.

Onigbinde, A. O. & Akinyele, I. O. (1988). Biochemical and nutritional changes in corn. (*Z. mays*) during storage at three temperatures. *J. Food Sci.*, **53**(1), 117–19.

Onayemi, O., Osibogun, O. A. & Obembe, O. (1986). Effect of different storage and cooking methods on some biochemical, nutritional and sensory characteristics of cowpea (*V. unguiculata*), *J. Food Sci.*, **51**, 153–5.

Sahn, I. P. & Nadezhnova, L. A. (1971). Changes in the in vitro digestibility of proteins contained in goats during storage. *Food Sci. Technol. Abstr.*, **10** MI, 116.

Satterlee, L. D., Marshall, H. F. & Tennyson, J. M. (1979). Measuring protein quality. *J. Am. Oil. Chem. Soc.*, **56**, 103–9.

Southgate, D. A. T. (1976). Determination of food carbohydrate. Applied Science Publishers, London, pp. 31–5.

Sowunmi, E. O. (1981). Biochemical and nutritional changes in corn (*Z. mays*) and cowpea (*V. unguiculata*) during storage. PhD thesis, Univ. of Ibadan, Nigeria.
Steel, R. G. & Torrie, J. H. (1960). *Principles and Procedures of Statistics*. McGraw-Hill, New York.
Van Twisk (1970). The keeping qualities of different grades of maize meal stored under different climatic conditions. *J. Food Technol.*, **5**, 287–94.