Food Chemistry **34** (1989) 35–39

Association Between Chemical Composition and Protein Digestibility of Heat-damaged Maize (*Zea mays*) Flour

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(Received 15 February 1988; revised version received and accepted 22 November 1988)

ABSTRACT

Whole maize flour stored at 55°C for 7 months was analyzed for changes of in vitro *protein digestibility and some chemical components. The changes in the total soluble sugars, free amino nitrogen, browning and moisture were strongly related to changes in protein digestibility. The association between browning and decrease in free amino nitrogen was not significant ($P > 0{\cdot}05$) and the decrease in the soluble sugars was about three times the decrease in free amino nitrogen per unit increase in browning (Hunters L-values), respectively.*

INTRODUCTION

Exposure of foods to mild or severe heat over a period of time is accompanied by changes in protein quality and chemical composition. The reductions in the sugar and amino acid contents of heat-damaged foods are associated with condensation reactions between the reducing hemiacetal or hemiketal carbonyl groups of carbohydrates and the amine groups of free or bound amino acids (Hodge, 1953; Ellis, 1959), with the formation of enzyme-resistant linkages. Information on compositional changes in heated foods in the literature has been limited to a few food items or model systems (Schroeder *et al.*, 1955; Oste & Sjodin, 1984). This study investigates changes in the protein digestibility of heat-damaged maize flour, and its association with non-enzymatic browning and some chemical components.

MATERIAL AND METHODS

Whole flour of maize (8339-17; IITA, Ibadan), milled to pass 0·55 mm sieve size, was stored (55 g each) in tightly screw-capped bottles of uniform dimensions (3·0 mm thick) at 55°C for 7 months. Three bottles were randomly removed monthly and the contents were separately homogenized and analyzed.

The *in vitro* protein digestibility was estimated by the method of Satterlee *et al.* (1979). Exactly 0·447 g of sample was digested with a 1 ml solution of 14·6 mg trypsin (227040 BAEE units) 28·6 mg chymotrypsin (1860 BAEE units) and 5·2 mg peptidase (0·520L—LEUCINE α—naphthylamide units) in 10 ml distilled water, followed by 1 ml of 11·2 mg (65 casein units) of bacterial protease in 10 ml distilled water. All enzymes were purchased from the Sigma Chemical Company, USA. The total soluble sugars were quantified by the phenol–sulphuric acid method (Dubois *et al.*, 1956) from a clarified 80% ethanol extract of the sample (Southgate, 1976) using sucrose as standard.

The free amino nitrogen was estimated by the formol titration of the extract of sample in distilled deionized water (1/10 w/v) using phenolphthalein as indicator (Harrow *et al.*, 1955). Browning was estimated as the decrease in Hunter, *L*- (lightness) values measured on a Hunter colour difference meter (MD 25 D2) and the moisture content by the standard air oven method (AOAC, 1980).

The pH was determined on a glass electrode pH meter (PYE Unicam MK-2) using the filtrate of a suspension of the sample (1/10 w/v) in distilled water.

STATISTICAL ANALYSIS

The significance of the variation in the data with time and replication was tested by the analysis of variance (ANOVA) and the means of triplicate readings were plotted against time (Figs 1 and 2). The regression equations and correlation coefficients (Table 1) were computed with the aid of a scientific calculator (Texas Instruments, TI-55111).

RESULTS AND DISCUSSION

The analysis of variance showed no differences between replicates but significant changes in the total soluble sugars, free amino nitrogen, browning and moisture ($P < 0·05$). The correlation between the decrease in the protein digestibility and the decrease in the soluble sugars, free amino nitrogen and moisture content was significant ($P < 0·05$). The increase in browning and the

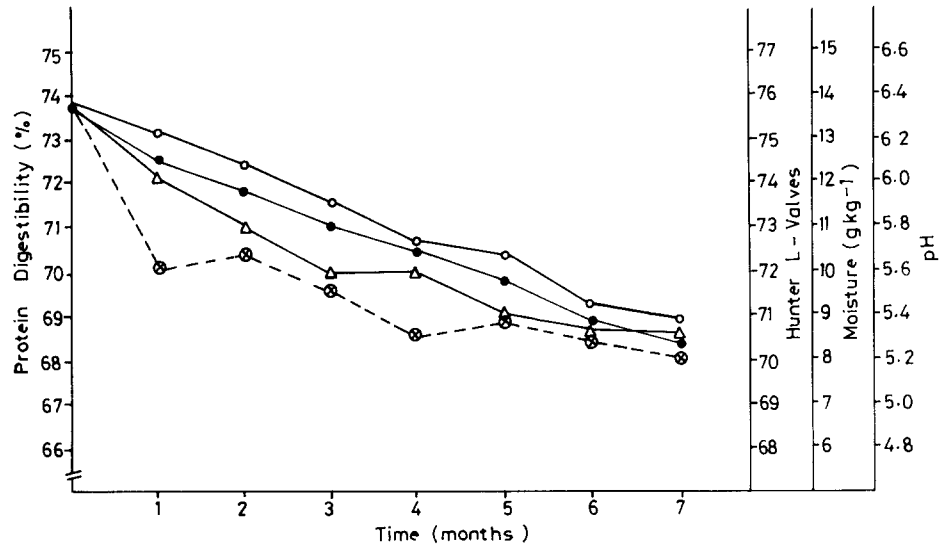

Fig. 1. Changes in the protein digestibility (●), Hunter *L*-values (⊗), moisture content (△) and pH (○) of heat damaged corn.

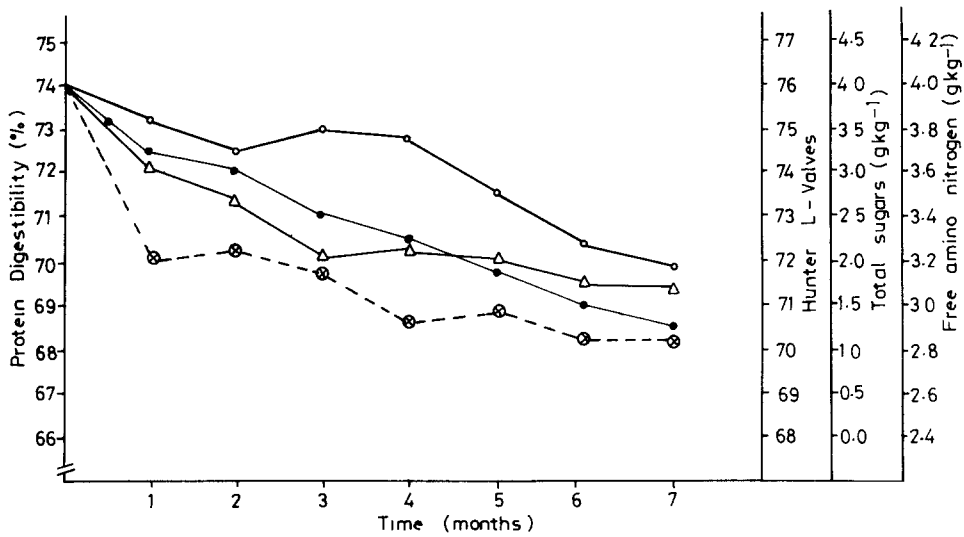

Fig. 2. Changes in the protein digestibility (●), Hunter *L*-values (⊗), total soluble sugars (△), and free amino nitrogen (○) of heat damaged corn.

TABLE 1
Regression Equations for the Association between the Changes in the Chemical Composition and Protein Digestibility in Heat Damaged Maize Flour

Variables		*Regression equations*	R^a
Y	*X*		
Protein digestibility	Browning	$Y = -0{\cdot}95x + 97{\cdot}70$	−0·91**
	Soluble sugar	$Y = 2{\cdot}43x + 64{\cdot}90$	0·97**
	Free amino Nitrogen	$Y = 5{\cdot}80X + 49{\cdot}90$	0·92**
	pH	$Y = 5{\cdot}01X + 41{\cdot}11$	0·98**
	Moisture	$Y = 0{\cdot}85X + 62{\cdot}12$	0·98**
Soluble sugars	Browning	$Y = -0{\cdot}39X + 13{\cdot}68$	−0·97**
Free amino nitrogen	Browning	$Y = -0{\cdot}12X + 7{\cdot}03$	−0·74**
pH	Browning	$Y = -0{\cdot}17X + 10{\cdot}86$	0·87*
Browning	Moisture	$Y = -1{\cdot}10X + 41{\cdot}43$	−0·93**
pH	Soluble sugars	$Y = 0{\cdot}48X + 4{\cdot}73$	0·95**
	Free amino nitrogen	$Y = 0{\cdot}68X + 3{\cdot}53$	0·67
Soluble sugar	Free amino nitrogen	$Y = 2{\cdot}05X + -4{\cdot}91$	0·82*

[a] Linear correlation coefficient.
Significant $*P < 0{\cdot}05$; $**$ $P < 0{\cdot}01$.

decrease in free amino nitrogen were not significantly correlated ($P > 0{\cdot}05$). The decrease in the pH of the samples related significantly to the changes in protein digestibility, browning and soluble sugar but the changes in the free amino nitrogen did not.

The positive correlation (Table 1) between the changes in soluble sugars and free amino nitrogen, and the negative correlation between the two parameters and browning were consistent with their formation in Maillard reactions (Ellis, 1959). The regression coefficients, however, show that soluble sugars decreased at a rate three times (0·39) higher than the rate of decrease in free amino nitrogen (0·12) per unit increase in browning. This suggests that the sugars might be lost through other mechanisms in addition to glycosylamine formation. Such possible mechanisms include the dehydration and degradation of the carbohydrates into products such as succinic, formic, acetic and pyruvic acid (Burton & McWeeney, 1964; Fagerson, 1969; Jurch & Tatum, 1970). This may partly explain the decrease in pH of the samples. The Hunter *L*-value is not a true measure of the glycosylamine linkages and this may be responsible for the significance in the browning without a corresponding decrease in the protein digestibility.

In conclusion, these preliminary findings show that the changes in the physico-chemical parameters and the decrease in the protein digestibility

were significantly correlated. It was, however, noted that the overall decrease in the protein digestibility was not significant. This observation is particularly relevant to the incidence of browning in roasted sun-dried corn grains (*guguru*) which is a popular snack in Nigeria.

ACKNOWLEDGEMENT

The authors thank Dr M. H. Love, Jowa State University, USA, and Department of Human Nutrition, University of Ibadan, Nigeria, for the facilities and Miss, Y. F. Oyebamiji for typing the manuscript.

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