

Some chemical options for the control of hard to cook and the associated browning in boiled cowpea (*V. unguiculata*)

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Abstract

Long cooking time is a problem militating against a wider dietary exploitation of the high protein contents of many grain legumes. Addition of CaHCO_3 (calcium bicarbonate) and a crude rock salt of carbonates (*kaun*) are the traditional methods of alleviating this problem in most Nigerian homes. However, this treatment also enhances browning; hence it is important to look for alternatives to the carbonates. The effects of some salts and organic acids on the cooking quality of a white variety of cowpea (*V. unguiculata*) was studied. The cookweights increased by 13.5, 23.8 and 28.7% with addition of hydrogencarbonate, carbonate and hydroxide of sodium, and by 16.65, 21.1 and 21.5% with addition of the hydrogencarbonate, hydroxide and carbonate of potassium. Addition of chlorides of sodium, potassium and calcium decreased the cookweight by 0.5, 8.5 and 13.5%, respectively ($p > 0.05$). Addition of the carbonates of sodium and potassium increased the browning of the grains ($p < 0.01$), but addition of organic acids and chloride salts of sodium, potassium and calcium, respectively, reduced the browning (A430 nm) ($p < 0.01$). Citric acid was suggested as an alternative to the traditional use of carbonates for boiling cowpea. © 1999 Elsevier Science Ltd. All rights reserved.

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1. Introduction

Heat processing of food results in several structural and chemical changes which account for the improvement in the nutritional and sensory qualities associated with most cooking processes (Bressani & Elias, 1974; Kinsella, Damodaran & German, 1985). During boiling, the water molecules serve as heat conductors for the denaturation of the highly folded polymeric proteins and carbohydrates, and stabilize the denatured conformation by interacting with the hydrophilic residues of the polymers (Busk, 1984). Water also provides a medium for the reaction of food components to form several products, some of which are important for sensory and nutritional quality of the food. However, the effectiveness of moisture at performing these functions could be affected by several environmental factors

such as the pH, temperature and both the types and concentration of the chemical groups in the medium. Modification of pH and addition of calcium salts have been widely used to manipulate the gelation and coagulation properties of milk proteins (Green & Marshall, 1977; Kalab & Emmons, 1972). Similarly, the thermal coagulation properties of egg-albumin and sesame α -globulin can be affected by the ionic species in the solution (Prakash & Nandi, 1977; Shimada & Matsushita, 1981). Since legumes still play significant roles in dietary protein supply, especially in the developing world, the limitation imposed on a wider consumption of several legumes by their long cooking time has generated interest in the phenomenon and its control. Addition of calcium salts and citrates reduce the cooking time of grain legumes (Muller, 1967; Rockland & Jones, 1974). Our study on the effect of pH also suggested that alkalinity enhances cooking (Onigbinde & Onobun, 1993). However, these conditions could also enhance browning reactions. Phenolics, as found in cowpeas (Akinyele, Onigbinde, Hussain & Omolulu, 1986), react under alkaline conditions to form linkages which have anti-nutritional consequences (Adrian, 1974; Finot, 1986). It

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was therefore considered necessary to investigate the possibility of reducing the cooking time of legumes without any damage to the protein quality. This communication is the outcome of a study of some common salts and food acids as possible alternatives to the traditional use of carbonates in the boiling of legumes.

2. Materials and methods

2.1. Materials

Cowpea with white testa were purchased locally and manually sorted for sound and mature grains. The salts and acids were reagent grade sodium hydrogen carbonate, sodium carbonate, sodium chloride, sodium hydroxide, potassium hydrogen carbonate, potassium carbonate, potassium chloride, potassium hydroxide, calcium carbonate, calcium chloride, calcium hydroxide, acetic acid, citric acid, lactic acid and tartaric acid.

2.2. Methods

Stock 0.1 M solutions of each of the above reagents were prepared and used as media for the boiling of cowpea grains, except calcium carbonate, for which a 0.1 M suspension was used.

2.2.1. Effect of ionic environment on cooking quality

Lots of 50 mature grains were weighed and placed in flat-bottom flasks containing 100 ml of each of the salt solutions and the systems were allowed to boil under reflux (100°C, 30 min). This was enough for optimum moisture absorption without significant solid matter leaching. The boiling was stopped and the weight measured after allowing the grains to cool to room temperature. The decanted steep water was filtered through Whatman no. 1 paper and the absorbance of the filtrate was recorded at 430 nm (Onigbinde & Onobun, 1993) using the respective salt solution as a blank.

2.2.2. Effect of salt concentration on cooking quality

A concentration range of 2.5 to 25.0 mM of NaOH, KOH and an equivalent of CaCO₃ in distilled water were used for this study. The grains were boiled in the solutions at each of the concentration levels and the cookweights and browning were estimated as described above.

2.2.3. Effect of organic acids on moisture absorption

2.2.4. Calculations

1. Moisture absorbed = $\frac{W_f - W_i}{W_i} \times \frac{100}{T}$
2. Reagent effect quotient (REQ) = $\frac{(V_f - V_c)}{V_c} \times \frac{100}{T}$
3. Mean \pm SD was calculated and the ANOVA and

correlation analyses were done to ascertain the effects of the concentration and time (Steel & Torrie, 1980).

3. Results and discussion

The results are presented in Tables 1–3. It can be observed from Table 1 that the cookweights of the grains were affected by the ionic environment. The cookweights increased by 13.5 to 28.7% with addition of the hydroxide, carbonate and hydrogen carbonate salts of sodium and potassium but decreased by 6.3 to 13.5% with calcium salts. Browning was increased by the hydroxide, carbonate and hydrogen carbonates of potassium and sodium, with the highest (> 500%) being in K₂CO₃ and Na₂CO₃. Although the differences in the effects of potassium and sodium salts were not significant, the cookweights were generally lower in calcium salt solutions than in the corresponding solutions of sodium and potassium ions ($p < 0.05$). The data also show that the grains experienced reduced cookweight and browning in the presence of chloride ions, irrespective of the cations.

Table 2 also suggests a significant correlation between swelling quality and browning in KOH and NaOH within a concentration range of 2.5 to 25.0 mM. The cookweights increased by as much as 15.1 and 18.6% with increase in the concentration of KOH and NaOH from 2.5 to 20 mM, respectively. The cookweights were generally below the control in CaCO₃ with the least value at 25 mM ($p > 0.05$). Browning increased with

Table 1
Effects of some salts on browning and swelling quality of boiled cowpea grains [mean ($n = 3$) \pm SD]

Salt solutions (0.1 M)	Cookweights (kg)	Moisture absorbed (kg)	Browning (A430 nm)
<i>Potassium</i>			
Hydroxide	2.35 \pm 0.04	1.35 (+21.1) ^a	0.46 \pm 0.07 (+18.0)
Bicarbonate	2.30 \pm 0.02	1.30 (+16.6)	0.73 \pm 0.01 (+87.2)
Carbonate	2.34 \pm 0.02	1.36 (+21.5)	\geq 2.00 (\geq 500)
Chloride	2.02 \pm 0.09	1.02 (−8.5)	0.28 \pm 0.03 (−28.2)
<i>Sodium</i>			
Hydroxide	2.44 \pm 0.08	1.44 (+28.7)	0.54 \pm 0.02 (+38.5)
Bicarbonate	2.27 \pm 0.02	1.27 (+13.5)	0.61 \pm 0.02 (+56.4)
Carbonate	2.38 \pm 0.02	1.38 (+23.8)	\geq 2.00 (\geq 500)
Chloride	2.11 \pm 0.03	1.11 (+0.5)	0.34 \pm 0.08 (−12.8)
<i>Calcium</i>			
Hydroxide	2.05 \pm 0.02	1.05 (−6.3)	0.56 \pm 0.06 (+43.6)
Carbonate	2.01 \pm 0.01	1.01 (−10.3)	0.36 \pm 0.07 (−7.7)
Chloride	1.97 \pm 0.05	0.97 (−13.5)	0.12 \pm 0.05 (−69.2)
Control (water)	2.12 \pm 0.02	1.12	0.39 \pm 0.06

Weight before boiling = 1 kg.

^a Values in parentheses are the percent changes (%) with respect to control.

Table 2
Effects of salt concentration on swelling quality and browning of cowpea

Concentration (mM)	Cookweight (g) ^a			Browning (A430 nm)		
	A	B	C	A	B	C
Control (water)	211.20 ± 1.45	211.20 ± 1.45	211.20 ± 1.45	0.39 ± 0.06	0.39 ± 0.06	0.39 ± 0.06
2.5	220.50 ± 1.44 (4.4)	217.85 ± 1.05 (3.1)	208.50 ± 1.85 (-1.3)	0.57 ± 0.05 (46.2)	0.53 ± 0.02 (35.9)	0.48 ± 0.09 (23.1)
5.0	219.50 ± 0.85 (3.9)	228.50 ± 0.80 (8.2)	205.50 ± 4.50 (-2.7)	0.53 ± 0.07 (35.9)	0.59 ± 0.08 (51.3)	0.38 ± 0.01 (-2.6)
10.0	233.50 ± 4.50 (10.6)	239.50 ± 2.25 (13.4)	209.35 ± 1.65 (-0.9)	0.56 ± 0.05 (43.6)	0.69 ± 0.02 (76.9)	0.38 ± 0.01 (-2.6)
15.0	234.00 ± 3.35 (10.8)	247.3 ± 2.85 (17.1)	206.50 ± 2.65 (-2.2)	1.50 ± 0.05 (284.6)	1.87 ± 0.09 (379.5)	0.34 ± 0.03 (-12.8)
20.0	243.00 ± 7.05 (15.1)	250.50 ± 1.20 (18.6)	205.50 ± 3.50 (-2.7)	> 2.00 (NM)	> 2.00 (NM)	0.35 ± 0.03 (-10.3)
25.0	240.50 ± 4.75 (13.9)	241.35 ± 5.25 (14.3)	204.00 ± 5.65 (-3.4)	> 2.00 (NM)	> 2.00 (NM)	0.34 ± 0.01 (-12.8)

^a Initial dry weight = 100 g.

Values in parentheses are % changes from the control.

A, potassium hydroxide; B, sodium hydroxide; C, calcium carbonate; NM, higher than measurable.

Table 3
Effects of organic acids on the cookweight and browning of cowpea

Media solution	Changes after boiling for 30 min (100°C)			
	Cookweight (g%)	REQ ^a —weight (%)	Browning (A430 nm)	REQ ^a —browning (%)
(0.1 M)				
Control (water)	211.5 ± 1.5	—	0.39 ± 0.04a	—
Acetic acid	231.8 ± 3.2	+ 9.6	0.11 ± 0.00bc	-69.4
Citric acid	220.6 ± 3.1	+ 4.3	0.12 ± 0.02b	-66.7
Lactic acid	207.7 ± 3.5	-1.8	0.09 ± 0.00c	-75.0
Tartaric acid	206.1 ± 1.5	-2.6	0.10 ± 0.01bc	-72.2

^a Reagent effect quotient (per cent change from control).

Values with different letters are significantly different ($p \leq 0.05$).

concentration of KOH and NaOH with a peak at 20 mM; but decreased in CaCO₃ beyond 2.5 mM. Analysis of variance (ANOVA) showed a more significant effect of the salt used than the concentration; the cookweights were lower in the presence of CaCO₃ than in the alkaline solutions ($p < 0.05$). Addition of organic acids (Table 3) increased the cookweight by 18% in acetic acid and 11% in citric acid, but the weight was decreased by 4 and 5% in lactic and tartaric acids, respectively. Investigation of the moisture absorption under room condition (25°C; not reported) showed that the permeability of the grains was reduced when the organic acids were added.

According to Busk (1984), the swelling of food grains during cooking can be affected by factors which interfere with the interaction of water molecules with the hydrophilic groups of the polymeric nutrients. The hydration of inorganic ions present in the medium of cooking, either as by-products of food degradation or dissociation products of salts added during processing, often competes with the hydrophilic groups of food

proteins and carbohydrates with consequent reduction in the amount of moisture immediately available for gelatinization processes (Busk, 1984; Carbonaro, Vecchini & Carnovale, 1993). The firmness, cell wall rigidity, poor permeability and hence poor cooking quality of some grain legumes have been attributed to the reaction of Ca²⁺ and Mg²⁺ with pectin to form insoluble calcium and magnesium pectates (Kumar, Venkataraman, Jaya & Krishnamurthy, 1978; Mattson, 1946). Retardatory effects of calcium on the softening of some other plant foods have also been reported (Howard & Buescher, 1990; Howard, Burma & Wagner, 1994). From these reports, low swelling of the cowpea grains in the presence of calcium salts could be a consequence of the poor dissociation effects of chloride ions, a condition further aggravated by the effects of calcium ions when CaCl₂ was added.

The increased cookweight in citric acid agreed with the reports of Badenhop and Hackler (1970) and Rockland and Jones (1974), although the effects of the other organic acids on cooking quality of grains have not

been reported. According to Muller (1967) citrate fixes Ca^{2+} and Mg^{2+} in the steep water to reduce the formation of pectates. The acidic effects could also cause the cleavage of the glycosidic and ionic linkages of pectin molecules, resulting in greater permeability (Howard et al., 1994). While both citric acid and acetic acid increased the cookweight of cowpea grains, the uptake of 81.2 (g%) moisture in acetic acid, in contrast to 69.1 (g%) in acetic acid under room conditions suggests that the former may require less heat for the grains to cook.

The reduction of browning when the organic acids were added could be attributed to the inhibitory effect of acidic pH on the development of non-enzymatic alkaline catalysed browning (Onigbinde & Onobun, 1993) by the acidic inactivation of phenolic groups and the possibility of the formation of complex ions with copper or iron (Luh & Daoud, 1975).

4. Conclusion

In conclusion, although the reduction of browning by 72% by addition of CaCl_2 may be of greater nutritional advantage than the 13.5% reduction in the cookweight, the inhibition of browning, increased cookweight and safety for food use make citric acid a possible alternative to traditional use of calcium salts. In addition, citric acid is cheap and the use of food sources such as fruit juice may also be explored.

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