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Technical Note

Effect of Extrusion Cooking on Nutritional Value of Rice Flour

ABSTRACT

Extrusion cooking, in a twin-screw extruder, of milled rice batter at 15% moisture and 120–150°C reduced total lysine content 11–13%, true digestibility 3%, biological value 4–5% and NPU 7–8% in growing rats.

INTRODUCTION

Extrusion cooking has been recommended for the production of weaning foods in developing countries because of the convenience and economy of cooking the starch without the need to dry the extrudate (Wilson & Tribelhorn, 1979). In a review of the effects of extrusion cooking on nutritional value, Björck & Asp (1984) reported reduction in total and available lysine content from the process. Reducing sugars presumably react with the ε-amino group of lysine and reduce the lysine content of the protein.

Noguchi *et al.* (1982) reported the denaturation of rice proteins soluble in phosphate buffer pH 7 during extrusion of milled rice at 200–240 °C. Mosqueda *et al.* (1986) confirmed that extrusion cooking of rice batters at 15% moisture at 120–150 °C in a twin-screw extruder resulted in a drastic decrease in gel viscosity of the rice flour without reduction in the rice's amylose content. Histochemical examination showed complete gelatinization of starch granules in the extrudate, but spherical protein bodies in the protein masses retained their structure while crystalline protein bodies did not.

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Because of the increasing popularity of extrusion cooking in the production of rice-based weaning foods (Payumo *et al.*, 1979; Bhumiratana, 1983) and in view of the extensive starch degradation during extrusion cooking (IRRI, 1985; Mosqueda *et al.*, 1986), the possible changes in nutritional value of rice flour proteins during extrusion cooking were studied.

MATERIALS AND METHODS

Samples of IR43 (16% amylose) and IR45 (25% amylose) batter were extruded cooked in a Werner and Pfleiderer twin-screw extruder model 37 (480 mm barrel length, 37·7 mm barrel diameter, 37·4 mm screw diameter, 4 mm diameter die hole, 140 rpm screw speed and 45 bars barrel pressure) at 15% moisture wet basis at 120, 135 and 150°C at a feeder rate of 160 g/min (Mosqueda *et al.*, 1986). Extrudate was ground to a flour with a Udy cyclone mill (60-mesh sieve) and analyzed for moisture at 135°C for 1 h (AACC, 1983), Kjeldahl protein by manual micro-Kjeldahl digestion followed by colorimetric assay of ammonia in digests by alkaline phenol-hypochlorite in an Auto-Analyzer using the factor 6·25 (Eggum *et al.*, 1977). Soluble protein was extracted from 100 mg of flour for 2–4 h using 2·00 ml 0·5M NaCl or 0·1M NaOH and determined by the Lowry method using a Folin–Ciocalteau reagent (Juliano & Boulter, 1976). Samples were hydrolyzed for 23 h in 6N HCl in sealed tubes after flushing with N_2 and analyzed with a Beckman Spinco amino acid analyzer 120C with PA-35 and AA-15 resins (Eggum *et al.*, 1977). Samples of raw and extrudate flours were airshipped to Copenhagen for nitrogen balance in growing rats.

In Copenhagen, nitrogen balance for each rice sample was measured in five Wistar male weaning rats, weighing 65–68 g, by the Thomas–Mitchell method (Eggum, 1973). The trial lasted 9 days—4 days introductory feeding and 5 days balance period in which N content of pooled feces and pooled urine was analyzed. The rat's daily diet had a constant amount of dry matter (10 g) and nitrogen (150 mg). Autoclaved potato starch was used to reduce the nitrogen of high-protein samples. Metabolic nitrogen and endogenous nitrogen were determined by adding ether-extracted freeze-dried egg (equivalent to 4% protein) to the N-free diet of autoclaved potato starch, sucrose, cellulose powder, soybean oil, minerals and vitamins (Eggum, 1973). Egg protein at this level is

completely utilized by rats. Energy value of food and feces was estimated with an IKA adiabatic calorimeter. Digestible energy of the diets was calculated by measuring the difference of energy in food and feces. Data were subjected to analysis of variance and standard deviation was calculated.

RESULTS AND DISCUSSION

Extrusion cooking of IR43 and IR45 milled rice at 15% moisture reduced both the 0·5M NaCl-soluble and 0·1N NaOH-soluble proteins, denoting denaturation not only of albumin-globulin but also of glutelin (Juliano & Boulter, 1976) (Table 1). The higher NaCl-soluble protein level in the extrudate at 150°C than at 120°C was unexpected because albumin and globulin should be sensitive to heat denaturation, as reported by Noguchi *et al.* (1982). However, Noguchi *et al.* (1982) extruded at 200–240°C as compared with 120–150°C in this study.

Alkali-soluble proteins were slightly lower in extrudates at 135°C and 150°C than at 120°C (Table 1). The reduced alkali solubility of extrudate protein can explain the presence of protein-rich particles in the dispersion of extrudate in boiling 0·2N KOH (Mosqueda *et al.*, 1986). Reduced alkali solubility of protein is also observed from boiling and parboiling of rice (Raghavendra Rao & Juliano, 1970; Eggum *et al.*, 1977; Tanaka *et al.*, 1978). In contrast, Noguchi *et al.* (1982) reported little change

TABLE 1
Effect of Extrusion Temperature on Protein Solubility and on Lysine Content of IR43 and IR45 Rice Extrudates at 15% Moisture[a]

Property	*Variety*	*Raw*	*Extrudate at*		
			120°C	*135°C*	*150°C*
0·5M NaCl-soluble proteins	IR43	10 ± 1	2 ± 1	2 ± 0	4 ± 0
(% of total proteins)	IR45	9 ± 0	1 ± 0	4 ± 0	5 ± 0
0·1N NaOH-soluble proteins	IR43	97 ± 7	37 ± 1	34 ± 3	34 ± 1
(% of total proteins)	IR45	88 ± 0	36 ± 4	34 ± 1	33 ± 1
Lysine (g/16 g N)	IR43	3·52 ± 0·01	3·49 ± 0·18	3·46 ± 0·16	3·06 ± 0·02
	IR45	3·66 ± 0·31	3·44 ± 0·43	3·02 ± 0·21	3·26 ± 0·21

[a] Mean ± standard deviation.

TABLE 2
Properties of Raw and Extrusion-cooked IR43 and IR45 Milled Rice Flour Extruded at 150°C, 50 Bars and 15% Moisture[a]

Property	*IR43*		*IR45*	
	Raw	*Cooked*	*Raw*	*Cooked*
Protein content (% N × 6·25)	7·50 ± 1·0	7·69 ± 0	8·62 ± 0	8·81 ± 0
Lysine (g/16 g N)	3·52 ± 0·01	3·06 ± 0·02	3·66 ± 0·31	3·26 ± 0·21
Cystine (g/16 g N)	2·80 ± 0·14	2·42 ± 0·20	2·62 ± 0·12	1·86 ± 0·20
Cystine + methionine (g/16 g N)	6·09 ± 0·31	5·58 ± 0·28	4·96 ± 0·02	4·32 ± 0·27
Energy content (kJ/g dry basis)	15·90 ± 0·06	15·67 ± 0·06	15·86 ± 0·06	15·87 ± 0·06
Balance in growing rats[b]				
Energy digestibility (% of intake)	97·9 ± 0·2	97·0 ± 0·2	97·1 ± 0·4	96·4 ± 0·4
True digestibility (% of N intake)	99·9 ± 0·3	96·9 ± 0·3	99·5 ± 0·5	96·2 ± 0·6
Biological value (% of absorbed N)	69·5 ± 0·7	65·9 ± 0·9	68·2 ± 0·6	65·6 ± 0·5
Net protein utilization (% of N intake)	69·4 ± 0·5	63·8 ± 1·0	67·9 ± 0·7	63·1 ± 0·7

[a] Mean ± standard deviation.
[b] Mean of five rats.

from extrusion cooking in rice protein solubility in 2% SDS-1% β-mercaptoethanol.

Lysine content of rice protein was reduced 17% by extrusion of 15% moisture batters at 135°C for IR45 and 13% for IR43 and 11% for IR45, both at 150°C (Table 1). Cystine content also decreased, but methionine content was not affected by extrusion (Table 2). Energy content was not affected by extrusion cooking but energy digestibility in growing rats was reduced 1%. A balance study in growing rats showed that extrusion of 15% moisture batters at 150°C decreased true digestibility 3%, biological value 4–5% and NPU 7–8% in the two rices. The decrease in NPU was less than the decrease in lysine content from extrusion cooking. Using the same processing conditions (15% moisture and 150°C), an experimental weaning food formulation of milled rice, dehulled mung bean and milk powder decreased in lysine content from 6·1 to 3·3 g/16 g of N after extrusion cooking. A blend of 60 parts rice flour and 35 parts full fat soy flour extruded at 130°C, to which five parts non-fat dry milk was subsequently added, had an NPU of 72% before and after extrusion (Payumo *et al.*, 1979).

The relative stability of rice flour protein during extrusion cooking may be due to the intact spherical protein bodies in the extrudate (Mosqueda *et al.*, 1986) which is the major form of protein bodies in the rice endosperm (Tanaka *et al.*, 1978). Rice flour also has low reducing sugar content (0·41 % glucose in IR43 and 0·35 % glucose in IR45 rice) and extrusion cooking did not substantially increase this (Mosqueda *et al.*, 1986). It is possible that, under more drastic extrusion cooking conditions wherein the protein bodies of rice are destroyed, greater decreases in nutritional value of the extrudate would be observed in the presence of reducing sugars, since the ε-amino group of the protein would be more accessible to condensation reactions (Björck & Asp, 1984).

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