In summary, data are presented which demonstrate that changes in functional properties of peanut protein are inducible by treatment with succinic anhydride. The uniqueness and value of these modified properties can be determined only through incorporating succinylated flours into food or beverage systems.

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Effects of Amylose Content on Some Characteristics of Parboiled Rice

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Forty-nine rice varieties have been analyzed to examine the influence of amylose content on parboiled and canned rice qualities. Statistical analysis shows a high positive correlation between amylose content and firmness of cooked or canned parboiled rice and appearance of canned rice. A parabolic-type relation was found between amylose content and milling yield. Rice with high amylose content is recommended for use by the canning industry. Formation of a chalky texture due to starch retrogradation may be avoided in cold meal by increasing the water content of rice.

The amylose content of starch is usually considered to be the main parameter of the eating characteristics of rice (Juliano, 1972). The texture of cooked rice is improved by increasing the amylose–amylopectin ratio (Juliano et al., 1965). According to Zakiuddin and Bhattacharya (1972), the difference in behavior between differently processed parboiled rices is due to the gelatinization and the retrogradation of the starch granules. The characteristics of the parboiled rice are dependent on the processing conditions: steeping time, steaming pressure, steaming time (Roberts et al., 1954; Bhattacharya and Subba Rao, 1966; Subrahmanyan, 1971; Dimopoulos and Muller, 1972; Feillet and Alary, 1975a,b).

According to Webb et al. (1968), amylose content is an indicator of dry matter (solids) loss during canning of parboiled rice. Varietal differences in the textural quality of canned rice have been attributed, at least partially, to variation in amylose content (Burns, 1972). This study was conducted to determine the effect of amylose content on other parboiled and canned rice characteristics.

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MATERIALS AND METHODS

Rice. Forty-nine rice varieties, listed in Table I, with amylose contents ranging from 21 to 29% (moisture free basis), were grown under controlled conditions at the experimental rice field of Mas d'Adrien (Station d'Amélioration des Plantes de Montpellier, Institut National de la Recherche Agronomique). After harvesting, paddy rices were stored in a room at 18 °C and 72–75% relative humidity; the final moisture content after 2 weeks was around 14.5% (wet basis).

Parboiling. Samples were parboiled in a fully automatic laboratory-scale apparatus in which time, pressure, and temperature of vacuum, steeping, and steaming can be programmed (Feillet and Alary, 1975a). In regard to our previous results, the following parboiling conditions were used: vacuum for 10 min under 1 bar; steeping for 30 min at 65 °C under 3.1 bars; steaming for 30 min at 120 °C. Parboiled rice was dried like paddy rice under very

Table I. Name, Type, and Amylose Content of Forty-Nine Rice Varieties

Name	Type[a]	Amylose[b] content	Name	Type	Amylose content	Name	Type	Amylose content
Vary Lava	Long	21.6	Cigalon à gros grain, peu perlé	Short	24.3	Starbonnet	Long	26.5
Césariot à glumelles bicolores	Long	22.7	Américano précoce à grain grossi	Short	24.5	Balilla à grain grossi	Short	26.6
Cigatrans court vitreux	Short	22.9	Cigalon	Short	24.6	Balilla θ	Short	26.7
Professeur Lamarque α	Long	23.0	Cigatrans 2	Short	24.9	Balilla à panicule lâche	Short	26.9
Césariot Hongrois précoce tallifère	Long	23.1	Américano issu de rampant	Short	25.1	Césariot βθ	Long	27.0
Cesariot raide tardif, grain fin	Long	23.3	Allorio θ	Long	25.3	Précoce corbetta à grain allongé	Long	27.1
Delta	Long	23.4	Cigalon court dressé	Short	25.3	Césariot Hongrois très précoce	Long	27.6
Césariot	Long	23.6	R 90	Short	25.4	Stirsia K à grain grossi	Long	27.9
Césariot à grain très long, non perlé	Long	23.7	Américano raide précoce	Short	25.4	Stirpe 136 à feuilles violettes	Long	28.4
Cigatrans à grain allongé	Short	23.8	Cristal	Short	25.5	Stirsia K	Long	28.4
Cigalon à grain allongé	Short	23.9	Eukei 71	Short	25.6	Précoce corbetta témoin	Short	28.4
Americano précoce	Short	23.9	Césariot à grain très long α x	Long	25.6	Stirsia	Long	28.4
Césariot à grain très long, perlé	Long	24.1	Balilla à grosse perle	Short	25.7	Arlésienne	Long	28.5
Césariot Hongrois tardif	Long	24.2	Balilla	Short	25.7	ds Alpha B	Long	28.8
Americano	Short	24.3	Stirpe 136	Long	26.1	ds Alpha C	Long	29.0
			Maratelli	Long	26.1	Stirsia β	Long	29.0
			Euribé	Long	26.4	Précoce corbetta raide à gros grain	Long	29.2

[a] Long type, kernel length >6.8 mm; short type, kernel length <6.8 mm. [b] Percent milled rice on a moisture-free basis.

mild conditions to minimize the influence of drying on milling yields.

Milling. Hulls were removed from the grain with a Olmia rubber-roll sheller manufactured in Italy. A Universale laboratory pearler was used to remove the bran; different settings were used with short and long grains (Feillet and Redon, 1971). Milling yield was expressed as the ratio of the whole milled rice weight over the cargo rice weight. Milling tests were run in duplicate; when the difference between two determinations was higher then 0.3%, the test was triplicated.

Rice Canning. Parboiled milled rice was canned in an excess of water according to the conditions of Webb and Adair (1970) with some modifications: milled parboiled rice (11 g) was transferred to a tin can (diameter, 71.5 mm; height, 43.5 mm; $^1/_6$ flat french standard); 100 ml of deionized water was added. The can was sealed, stirred for 3 min, and retorted in an autoclave for 20 min at 120 °C. After cooling, samples were stored for 1 month at 19 °C before evaluation.

When studying the change in firmness of canned rice during storage, another procedure was used: rice was cooked in an excess of water until the suitable moisture content was reached (65%, except when otherwise mentioned); after draining, cooked rice was poured in a tin can ($^1/_6$ flat french standard). Cans were retorted 25 min at 120 °C and then stored at 4 or 22 °C.

Amylose Content. The amylose content of over-milled rice was determined in duplicate as described by Juliano (1971) by measuring the intensity of the blue-colored complex of amylose with iodine; readings were performed at 620 nm. The standard error of the mean of duplicate determinations was 0.2%. Amylose No. 4561 from Merck was used as a standard. Under these conditions, the amylose content is 1% higher than when using potato amylose as standard.

Physical Characteristics of Parboiled Rice. Kernel aspect, i.e. shape deformation and cracking of kernel, was scored by visual inspection from 1 to 5 in the order of increasing quality. Yellowness occurring during parboiling was determined in duplicate by measuring the reflectance value of the samples at 475 nm (Feillet, 1970). The gelatinization degree of parboiled rice was obtained by soaking 10 kernels in water at 50 °C for 15 h; the number of kernels (N) with white spots was determined after pressing between two glass plates. The gelatinization degree of the sample is equal to $10N$.

Cooking Quality of Parboiled Rice. Fifteen grams of rice was transferred in 100 ml of deionized water kept at 98 °C. After 25 min, the cooked rice was immediately washed in running tap water (30 s), drained on a grid for 5 min, and weighed.

Water absorption is the amount of water absorbed by 100 g of rice (dry basis) during cooking. Firmness is the mean force (g) applied to extrude 13 g of cooked rice through a standard grid (Feillet and Alary, 1975a).

Characteristics of Canned Rice. Physical aspects of canned rice were scored by visual inspection from 1 to 5. Water absorption and firmness were determined as described for cooked rice; analyses were performed without or after heating the cans at 100 °C for 20 min.

RESULTS AND DISCUSSION

The quality of rice is the sum of milling characteristics, grain appearance, cooking and eating quality, and parboiling and canning behavior. In this study 49 rice varieties with different amylose contents have been parboiled under standard conditions. Then the following characteristics were evaluated: milling yield; appearance, yellowness, and gelatinization degree of parboiled rice; water absorption and firmness after cooking; and appearance, water absorption, and firmness after canning.

The matrix of correlation between all parameters is shown in Table II. The degree of gelatinization was maximum for all samples and related data were not included in the matrix.

Milling Yield. There is no linear relation between amylose content and milling yield of parboiled rice. A more accurate analysis shows the existence of a parabolic type relation between these two parameters (Figure 1): in a first step, the milling yield decreases when the amylose content increases, up to 25%; at higher amylose contents, the milling yield starts to increase and reaches its initial level. Nevertheless, the differences between samples are low and amylose content does not seem an important parameter of milling yield.

Table II. Matrix of Correlation of Characteristics of Parboiled Rice with Rice Amylose Content[a]

	Amylose content, per 100 d.b.[b]	Milling yield	Physical characteristics: Appearance	Physical characteristics: Yellowness	Cooking quality: Water absorption	Cooking quality: Firmness, g	Canned rice quality: Appearance	Canned rice quality: Water absorption	Canned rice quality: Firmness, g
Amylose content	1.00								
Milling yield		1							
Physical characteristics									
Appearance		0.61**	1						
Yellowness	0.37*	−0.35*	−0.54**	1					
Cooking quality									
Water absorption					1				
Firmness	0.62**	0.32*			−0.57**	1			
Canned rice quality									
Appearance	0.53**	0.38*	0.34*		−0.34*	0.73**	1		
Water absorption	−0.83**					−0.75**	−0.65**	1	
Firmness	0.83**					0.81**	0.61**	−0.85**	1

[a] **, significant at $P \leq 0.01$; *, significant $0.01 < P \leq 0.05$. [b] d.b., dry basis.

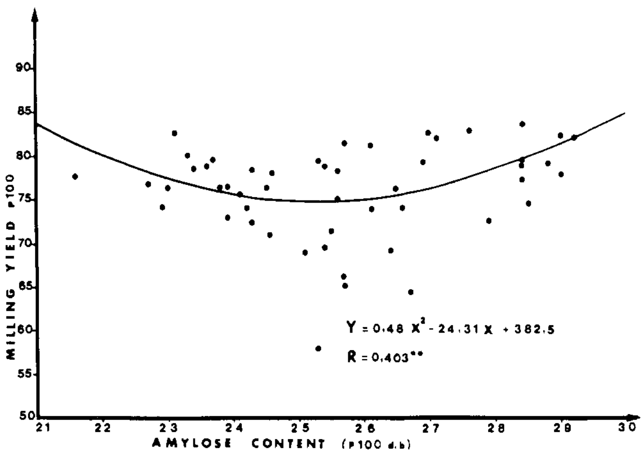

Figure 1. Effect of amylose content on milling yield of parboiled rice.

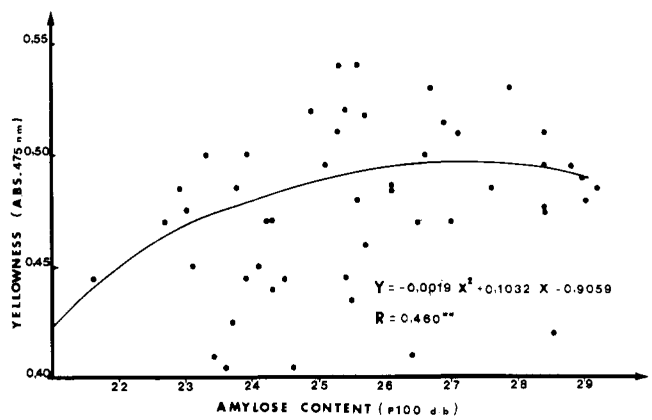

Figure 2. Effect of amylose content on yellowness of parboiled rice.

Short and long grain types were evenly distributed in the whole range of amylose content. Consequently, the correlation found between the milling yield and the amylose content is unbiased by the difference in the sample kernel sizes.

Appearance and Yellowness. High amylose content does not affect the appearance of parboiled rice before cooking, but has a slight positive effect on the yellowness and, consequently, lessens the overall aspect score (Figure 2). A higher parabolic type correlation between amylose content and yellowness was found: yellowness increases until the amylose content reaches 27 per 100 (dry basis) and then slightly decreases. Nevertheless, the possibility that the differences observed between samples could arise only from differences in bran or hull color cannot be ruled out.

The effect of amylose content on both milling yield and yellowness could explain the correlation between these two parameters ($r = -0.35$*).

Cooking Quality. An increase in amylose content improves the firmness of the cooked parboiled rice but has no significant effect on water absorption. A similar relation has been observed by several workers with white rice (Halick and Keneaster, 1956; Juliano et al., 1965; Rao et al., 1952). These results show that the influence of the amylose fraction on the cooking quality of white rice can be extended to parboiled rice.

Water absorption and firmness of cooked parboiled rice are strongly related ($r = -0.57$**). As shown by determination of partial correlation, the correlation coefficient between amylose content and water absorption is +0.66** when firmness is given; with constant water absorption, the correlation coefficient between amylose content and firmness is +0.80**. Consequently, parboiled rice swells more during cooking when amylose content is high while keeping a suitable firmness.

Canned Rice Quality. A noteworthy effect on canned rice characteristics is observed: the higher the amylose content is, the higher the firmness after canning is ($r = +0.83$**), the lower the water absorption is ($r = -0.83$**), and the better the appearance is ($r = +0.53$**). These three parameters are highly correlated together.

Changes in firmness during storage of the cans have also been examined. Results are given in Table III.

In agreement with the findings of Michiels (1974), an increase in firmness and formation of a chalky texture were observed during storage; changes were faster at 4 °C than at room temperature and disappeared, at least partially, by heating before analysis. As already outlined by Ferrel et al. (1960) and as more recently demonstrated by Charbonniere (1975) by x-ray analysis, changes during aging are associated with the retrogradation of gelatinized starch. Present data show that there is no direct effect of the amylose content on the modification of canned rice characteristics during storage. Nevertheless, important differences are observed between varieties; biochemical components and reactions involved in these phenomena are unknown. As illustrated in Table IV, the moisture content of rice has a direct effect on the change in rice firmness during storage (4 °C). Consequently, rice moisture content higher than 74 per 100 is recommended

Table III. Relative Changes in Firmness of Parboiled Canned Rice during Storage

Varieties	Amylose[a] content	Storage time, days: 15; Storage temp, °C: 22; Heating[b]	15; 22; No heating[b]	15; 4; Heating	15; 4; No heating	30; 4; No heating
Delta	23.4	100[c]	110	110	290	400
Cesariot	23.6	100	160	115	410	460
Cigalon	24.6	100	110	90	220	
Cristal	25.5	100	120	120	310	
Balilla	25.7	100	155	110	285	
Euribe	26.4	100	115	120	275	280
Cesariot $\beta\theta$	27.0	100	130	280	850	950
Arlesienne	28.5	100	100	105	165	185
Mean values	25.6	100	125	131	351	

[a] Per 100 dry basis. [b] Analysis after or without heating the cans. [c] For each variety, all firmness values were divided by a constant factor so that the firmness after storage at 22 °C and without heating before analysis is equal to 100.

Table IV. Effect of Rice Moisture Content on the Relative Firmness Value of Canned Parboiled Rice

Storage, time, days	H_2O per 100 (wet basis): 61	70	74	76
1	100[a]	100	100	100
7	162	185	158	157
15	178	187	163	168
30	217	214	149	149

[a] For each moisture constant, all firmness values were divided by a constant factor so that the firmness after 1-day storage time is equal to 100.

for cold meal canned products, i.e. salads.

CONCLUSION

The amylose content of rice, which is known to be an important factor of the cooking quality of white rice, has to be taken into consideration when examining the quality of parboiled and canned rice. Positive correlation does exist between amylose content and yellowness of milled parboiled rice, firmness of cooked parboiled rice, and appearance and firmness of canned parboiled rice. Comparison of several varieties shows that variation in amylose content does not explain all the differences between samples. Nevertheless, determination of amylose content would be useful as a screening test in a breeding program aimed at improving the overall quality of parboiled rice.

Utilization of high amylose rice by rice parboiling and canning processors is recommended.

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