Rheological Behavior of Venezuelan *Arepa* Dough from Precooked Corn Flour

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ABSTRACT

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Arepa, a traditional Venezuelan dish, is usually prepared from precooked corn flour. When mixed with water, the flour results in an adhesive dough. Effects of several variables on the adhesiveness of *arepa* dough were evaluated. When cooked, this dough becomes elastic. The effect of increased cooking time on the rheological, chemical, and physical properties of the dough was evaluated. Adhesiveness of the dough decreased with increasing rest time and with increased dough water level, and it increased with increased mix time. The relationship between particle size, adhesiveness, water absorption, consistency, and apparent viscosity of the dough was established. Rigidity and hydration capacity increased, and amylograph viscosity at 95°C decreased with increased cooking time. No effect on the susceptibility of the starch to enzyme attack was shown.

Arepas are the main cereal dish of Venezuela. Traditionally, *arepas* are made by cooking partially degermed corn until it is tender but not soft. The grain is ground in a metal burr hand mill and mixed with water and salt until the dough is of the appropriate consistency. *Arepas*, which are disk-shaped, are approximately 8.5 cm in diameter and 2.5 cm thick. They are either baked on a hot plate to form a crust and then baked in the oven, or they are boiled in water for about 5 min, allowed to cool, and then baked on a hot plate.

In urban areas, the more convenient method of making *arepas* from partially degermed corn is now used. Precooked corn flour is mixed with water and salt, and the dough is shaped and cooked by any of the traditional procedures.

Precooked corn flour has been a successful product, and *arepas* made from it have the same physical characteristics and palatability as do traditional *arepas*. The variables that determine the rheological characteristics of dough and *arepas* made from precooked corn flour have not been studied, however.

The purpose of this research was to evaluate the effect of several variables on the physical characteristics of Venezuelan *arepa* doughs made from precooked corn flour. These variables were: resting time, level of water, mixing time, particle size, and cooking time.

MATERIALS AND METHODS

Precooked Corn Flour

Commercial precooked corn flour from the retail market was used for all the experiments. Average physicochemical characteristics of precooked corn flour are (in percent): starch, 64.90; fat, 0.74; protein (N × 6.25), 7.65; ash, 0.34; and gelatinization, 83.60. Water absorption index (WAI), as determined by the method of Kite et al (1957), was 4.15 ml/g. The flour's crude protein, crude fiber, fat, ash, and moisture content were determined by AOAC methods (1980). Approximately 50 g of precooked corn flour was sieved through Tyler standard sieves for 15 min, using a Ro-Tap Testing sieve shaker. The particle size index (PSI) was expressed as the percentage of the original sample retained after sieving over a particular mesh.

Dough Preparation

The *arepa* dough (40% precooked corn flour, 59.4% water, and 0.6% salt) was prepared as follows, unless otherwise specified. Ingredients are mixed in a Farinograph at a constant temperature of 30°C and a mixing speed of 40 rpm for 2 min. *Arepa* dough cooked for different lengths of time was freeze-dried, pulverized, and the degree of gelatinization (Chiang and Johnson 1977) was then measured on the fraction that passed through an 80-mesh sieve. The amylograph procedure (Yasunaga et al 1968) was used to evaluate the effect of increasing cooking time on the *arepa* dough. A slurry was prepared by dispersing the *arepa* dough in distilled water with a Waring Blendor, the slurry was transferred to the amylograph bowl, and the amylograms determined with the 350 cm·g cartridge and normal heating cycle. The water hydration capacity was also determined following the same methodology.

Viscosity

To measure the viscosity, 500 ml of a 25% dispersion of *arepa* dough in water at 30° C was prepared and manually stirred for 30 sec to ensure a homogeneous suspension. The viscosity was measured at room temperature (23° C) in a Brookfield viscometer, model RVT, using spindle no. 5. The readings were taken after 1 min of rotation at each speed. Three different samples of precooked corn flour were also tested. As shown in Fig. 1, a clear distinction of the viscosity of the doughs could be obtained at 5 rpm; therefore, this speed was chosen for all subsequent experiments.

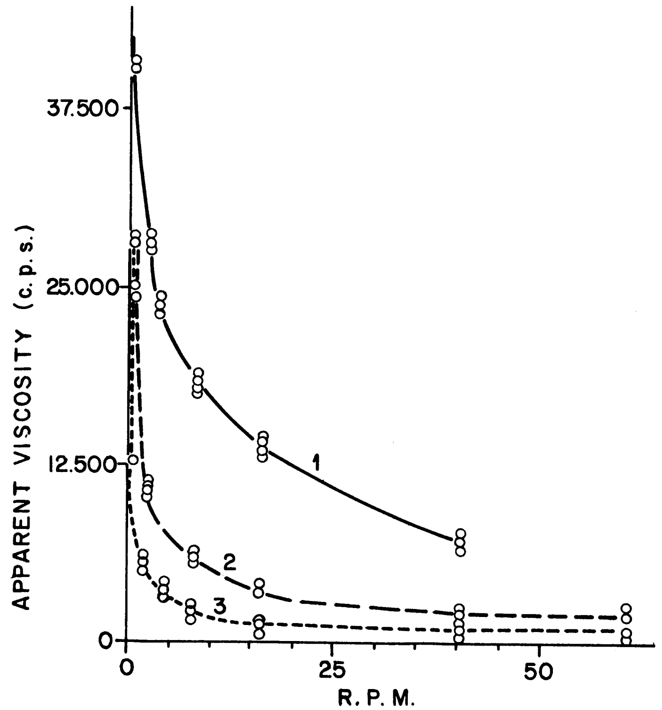

Fig. 1. Viscosity curves of *arepa* doughs made from three different lots of commercial precooked corn flour.

TABLE I
Particle Size Distribution of the Precooked Corn Flour

Tyler Screen Designation	Sieve Opening (mm)	Particle Size Index A[a]	Particle Size Index B[b]
35	425	19.8	...
42	355	29.4	2.1
48	297	16.2	3.2
60	250	10.1	7.5
80	180	10.4	47.9
Receiver	...	14.0	39.1

[a] A, Particle size index of commercial precooked corn flour.
[b] B, After pulverizing the flour in an Alpine mill.

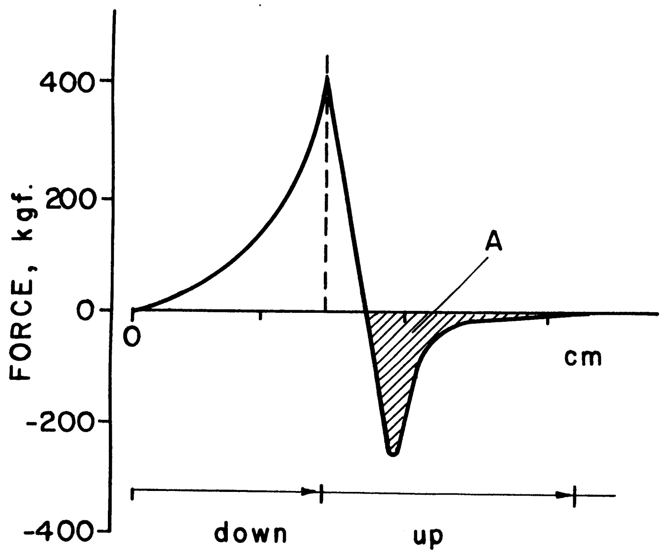

Fig. 2. Hardness and adhesiveness profile of *arepa* dough. A = adhesiveness.

Dough Consistency

The consistency of the *arepa* dough was measured in the Brabender Farinograph. The standard Farinograph method could not be applied because the particle size distribution of the precooked corn flour is extremely heterogeneous (Table I). Because water pickup is not uniform, large lumps form and impede uniform dough development. Dough consistency was measured by the following procedure: 200 ± 0.1 g of the flour (12% mb) were dispersed in 500 g of water (30° C), stirred for 1 min, poured in the Farinograph's large mixing bowl, and mixed for 10 min at 30° C and 63 rpm.

Adhesiveness and Hardness

The Instron Universal Testing machine, using a load cell of 453.59 kgf, was used to measure the adhesiveness and hardness of *arepa* doughs. Instron settings were 12.7 cm/min and 25.4 cm/min for the crosshead and chart speeds, respectively. *Arepa* dough weighing 200 g was manually shaped into a disk 3 cm thick and 9 ± 0.2 cm in diameter and was compressed to 20% of its thickness (80% compression) with an acrylic plunger having an area of 158.36 cm^2. After 1 min, the plunger was withdrawn from the dough. Figure 2 is a direct tracing of a force-distance curve drawn by the Instron. The maximum height in the compression cycle was defined as hardness (Bourne 1968). The negative force area, defined as adhesiveness, represented the work necessary to pull the compressing plunger away from the sample.

Rigidity in the Elastic Range

Arepa doughs, made with the precooked corn flour and weighing an average of 69 g each, were shaped into disks 7 cm thick and 1.7 cm in diameter, packed in polyester/polyethylene bags, and cooked

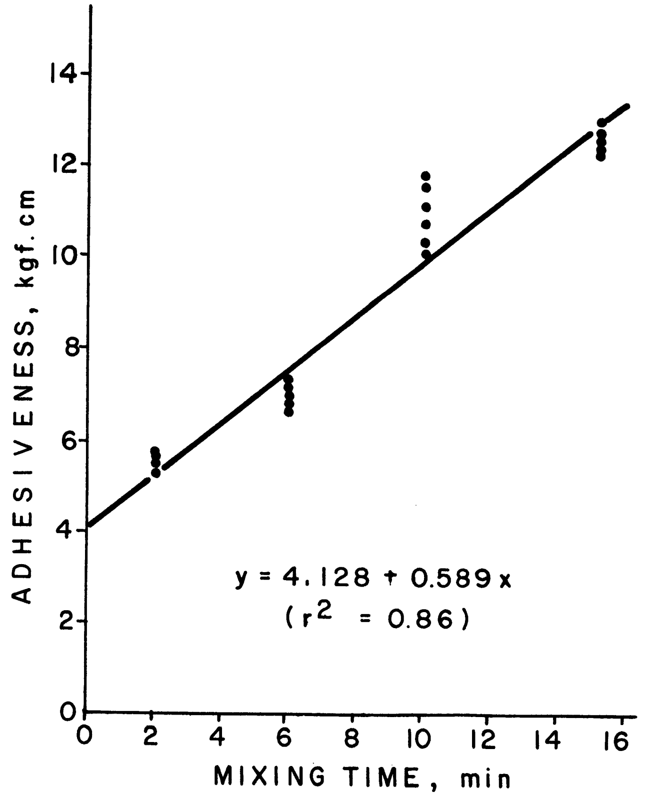

Fig. 3. Effect of mixing time on the adhesiveness of *arepa* dough.

in boiling water for different lengths of time. The doughs were then placed between two pieces of wire screening until they reached room temperature (25° C). The Instron Universal Testing machine (crosshead speed, 5.08 cm/min; chart speed, 30.48 cm/min) was used to measure rigidity or stiffness. An acrylic plunger having an area of 68.5148 cm^2 was used to compress the disks. The modulus of elasticity, E, which is the ratio of stress to strain within the elastic range of the material (Mohsenin and Mittal 1977), was used to evaluate the rigidity of the cooked *arepa* dough. It was calculated from the formula

$$E = \frac{F/A}{\Delta l/l}$$

where F = force, A = sample cross-sectional area, Δl = deformation due to applied force, and l = initial length of the sample.

TABLE II
Effect of Rest Time on the Adhesiveness of *Arepa* Dough

Time (min)	Adhesiveness[a] (kgf/cm)
0	7.4 ± 0.8
10	5.5 ± 0.4
20	4.8 ± 0.3
60	4.1 ± 0.2
120	4.0 ± 0.1

[a] Mean and standard deviation based on 10 replications.

TABLE III
Effect of Water Level on Hardness of *Arepa* Dough

Water Level (%)	Hardness[a] (kgf)
50	161.5 ± 2.7
55	126.0 ± 1.2
60	69.2 ± 1.0
65	23.2 ± 1.8

[a] Mean and standard deviation based on four replications.

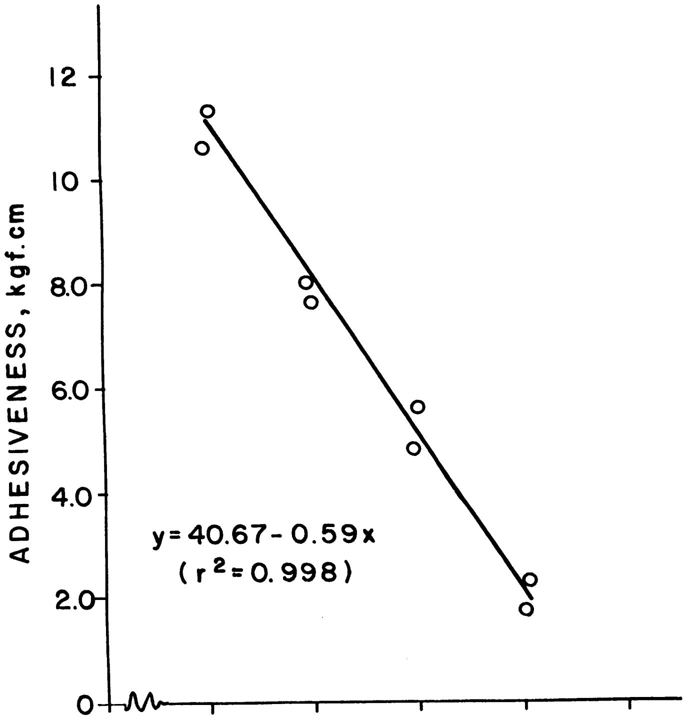

Fig. 4. Effect of water incorporated in the dough on adhesiveness.

RESULTS AND DISCUSSION

Effect of Mixing Time on the Adhesiveness of *Arepa* Dough

The adhesiveness of dough increased substantially as a result of mixing (Fig. 3). After 6 min of mixing, the dough became too sticky to be shaped easily, probably because of the increasing amount of free starch. Mullins et al (1955) stated that the presence of free starch is responsible for the adhesiveness of cooked starchy products.

Effect of Rest Time on the Adhesiveness of *Arepa* Dough

The dough was mixed for 2 min in the Farinograph's large mixing bowl. During its resting time, the adhesiveness was

TABLE IV
Effect of Particle Size on Physical Properties of Precooked Flour and *Arepa* Dough

Sample	Adhesiveness (kgf/cm)	Viscosity (cps)	WAI[a] (ml/g)	Consistency (BU)[b]
A[c]	5.4 ± 0.8	6.850 ± 800	4.1 ± 0.1	277.0 ± 3.5
B[d]	9.0 ± 2.0	17.620 ± 1,000	4.0 ± 0.1	405.0 ± 7.0

[a] WAI = water absorption index.

[b] BU = Brabender units.

[c] Approximately 75.5% of total retained over 60 mesh.

[d] Approximately 60.7% of total retained over 80 mesh.

TABLE V
Effect of Cooking Time on the Gelatinization of *Arepa* Dough

Cooking Time (min)	Gelatinization (%)[a]
0	85.7 ± 3.1 a
2	87.2 ± 4.0 a
4	86.7 ± 4.1 a
6	85.0 ± 6.2 a
8	99.8 ± 0.1 a
10	98.2 ± 1.7 a

[a] Mean and standard deviation based on six replications. Means followed by the same letter are not significantly different at $P < 0.05$.

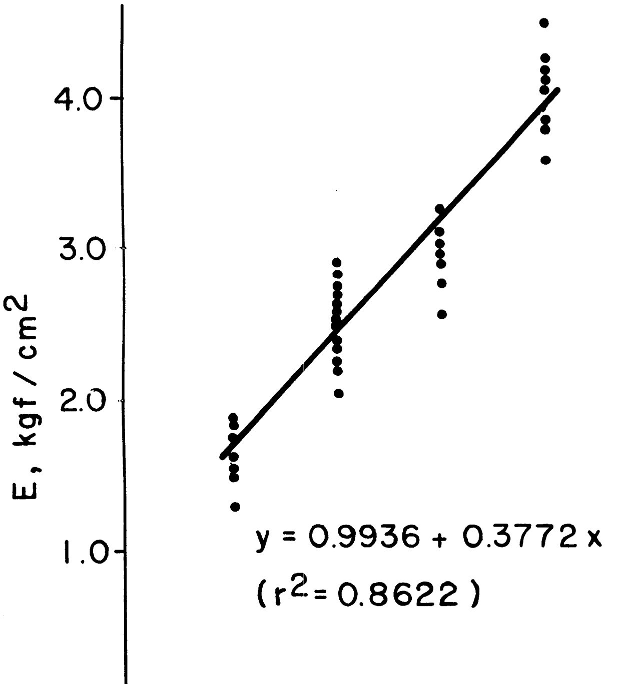

Fig. 5. Effect of cooking time on rigidity of *arepa* dough.

measured at regular intervals (Table II). There was an initial reduction of 25.6% in the adhesiveness of the dough within the first 10 min of rest, and a 12.6% reduction in the following 10 min; after 20 min, there was not a significant reduction in the adhesiveness. Furthermore, the handling characteristics of the dough could be improved by simply allowing the dough to rest after it had been mixed with water and before the *arepas* were shaped. Working with reconstituted yam dough, Breenan and Sodah-Ayernor (1973) found that its physical properties changed drastically with post-reconstitution time; they attributed these changes to starch retrogradation. Because of the association of amylose linear chains, the amount of free starch decreases; therefore, the adhesiveness is reduced.

Effect of the Water Level on *Arepa* Dough's Adhesiveness and Hardness

Having all variables constant, the dough's hardness showed a sharp decrease when the level of added water was increased from 50 to 65% (Table III). The lowest adhesiveness was obtained with dough prepared with 65% added water (Fig. 4). It was too soft and very difficult to handle and shape. On the other hand, dough made with 50% added water was too dry, hard, adhesive, and was almost impossible to shape. An acceptable dough with good handling characteristics was produced with a range of 55–60% added water.

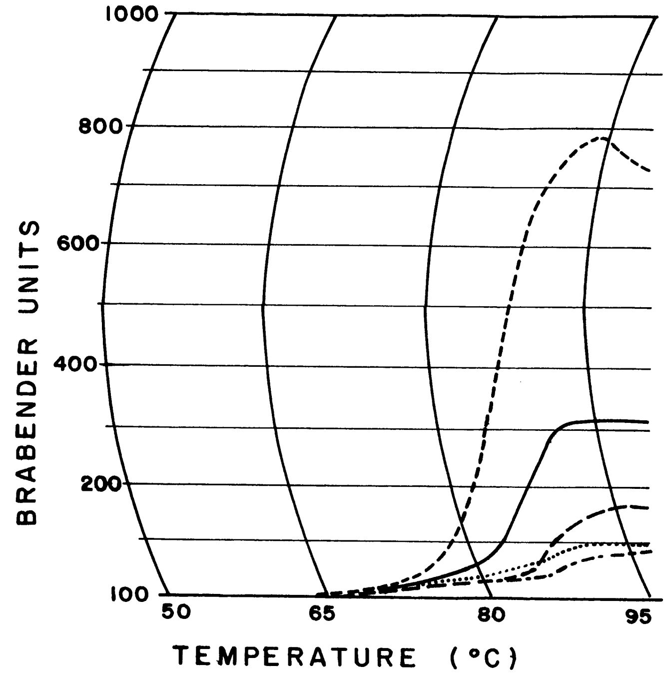

Fig. 6. Amylograms of boiled *arepa* doughs. ----- = 0 min; —— = 2 min; ——— = 4 min; ······· = 6 min; —·—·—· = 8 min.

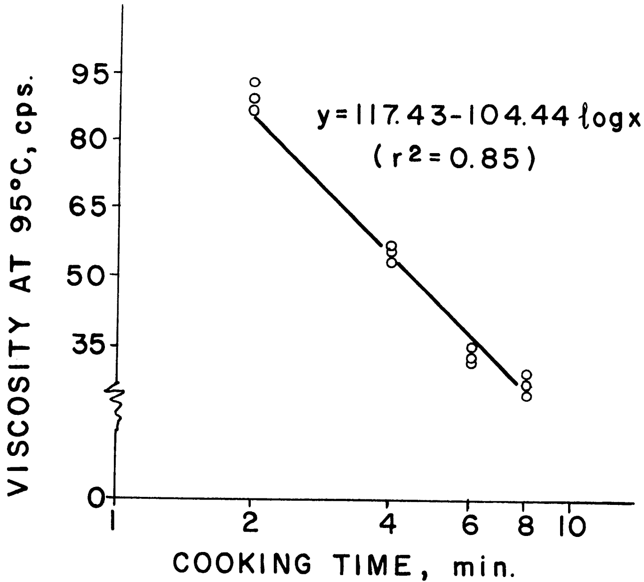

Fig. 7. Viscosity of an aqueous suspension of *arepa* dough cooked for different lengths of time.

Effect of Particle Size on the Physical Properties of *Arepa* Dough

The precooked corn flour used to make Venezuelan *arepas* has a very heterogeneous particle size distribution; approximately 75.5% of the total is retained over 60 mesh. A sample of the flour was milled in a pulverizing Alpine mill until approximately 60.7% of the total was retained over 80 mesh. The reduction in particle size resulted in a drastic change in the physical characteristics of the dough (Table IV). The viscosity, consistency, and adhesiveness increased as a result of the reduction in particle size. WAI decreased slightly for the finer flour fraction. This method measures entrapped and absorbed water. Because particle size has a positive effect on the trapped water, it is not possible to determine the changes in the absorbed water.

Effect of Cooking Time on Rigidity and Starch Gelatinization of *Arepa* Dough

The effect of increased cooking time on the rigidity of *arepa* dough is shown in Fig. 5. (E is the maximum value of modulus of elasticity.) Rigidity increased linearly with increasing cook time. After cooking the *arepa* for 2 min, an elastic layer was formed around the product, but the inner portion remained uncooked. As a result, the *arepa* was adhesive. After 5 min of cooking, adhesiveness was lost, and the *arepa* became elastic. Traditionally, *arepas* are boiled for about this period of time to obtain a completely cooked product.

Table V shows the effect of cooking time on gelatinized starch, measured with glucoamylase and *o*-toluidine reagent (Chiang and Johnson 1977) in *arepa* dough. Statistical analysis of the data showed no significant difference in the gelatinization of the different samples. Apparently, the change in rigidity resulting from increased cooking is not due to increased starch gelatinization. A similar observation was made by Paton and Spratt (1981). They indicated that starch granules can undergo 100% loss of optical birefringency and yet not be completely cooked. Degree of cooking is a more advanced state generally associated with irreversible swelling, which results in changes of the functional behavior.

Amylograms and Hydration Capacity of Boiled *Arepa* Dough

Amylograms of the slurries prepared from the *arepa* dough and cooked for different lengths of time are shown in Fig. 6. The amylograms did not show the appearance of peaks, which are related to the gelatinization of starch. There was a substantial decrease in the viscosity at 95°C, with the increase in the cooking

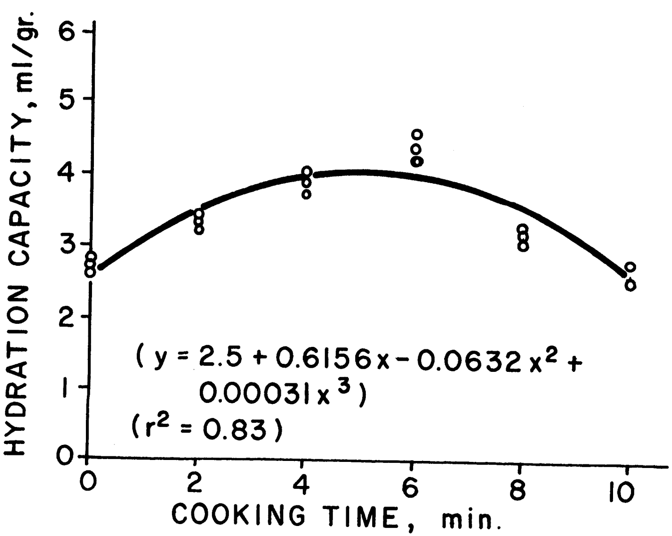

Fig. 8. Effect of cooking time on the hydration capacity of *arepa* dough.

time (Fig. 7). The effect of increased cooking time on the hydration capacity of boiled *arepa* dough was evaluated by the procedure of Yasunaga et al (1968). Hydration capacity increased with time to a maximum at 6 min, decreasing with further increase in cook time (Fig. 8). These changes in functional behavior are not changes in the degree of gelatinization. They may be due to changes in the molecular organization of the starch. Similar observations have been reported by Anderson et al (1969) and Mercier et al (1979). They studied the functional behavior of extrusion-cooked cornmeal and starch pastes and found that final cooked paste viscosity (50° C) decreased with the increase in barrel temperature. WAI increased up to a certain temperature, and decreased after that. Mercier et al (1979) showed that the factors involved during cooking of starches lead to different structural modifications of the granule.

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