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PREGELATINIZED CARA (WATER YAM) FLOUR: EFFECT ON DOUGH AND BREAD QUALITY[1]

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ABSTRACT

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Pregelatinized cara flour was prepared by paring, cutting, and boiling cara for 50 min. After cooling, the cara was spray-dried into flour. A study was made of the effect of addition of this flour on the properties of dough made from medium strength wheat flour using the standard flour-water dough (FWD) system and in the presence of the other baking ingredients (bread dough [BD] system). In the FWD system, the water absorption increased while the mixing requirements decreased. The dough also showed a significant increase in resistance to extension and maximum resistance to extension, indicating an oxidative effect. On testing the dough properties in the BD system, however, the mixing requirements were not affected, and the dough resistance to extension and extensibility remained essentially constant up to the 10% level. Testing the performance of any composite flour dough in a BD system is recommended to permit measuring and accounting for the collective effect of all baking ingredients. When the baking test was conducted with dough consistency adjusted to 500 farinograph units, bread with 7.5% cara flour had excellent volume and quality, although using 0.25% calcium stearyl-2-lactylate at the 10% level was necessary.

Consumption of wheat, particularly in developing countries, is continually increasing. In many of these countries, demand has surpassed production, thus forcing importation of wheat, which can be obtained only by payment in hard currency in most cases. This expenditure imposes a burden on the development program. The situation can be alleviated either by increasing the wheat production via improvement of agricultural practices or by replacing at least part of the imported wheat flour with flours that can be produced locally. A program has been initiated in the breadmaking industry to use flours of various tropical and subtropical crops to reduce the need for imported wheat. One of these crops, which can be grown in relatively poor soil with a yield of 4–6 tons/acre, is water yam, or cara (*Dioscorea alata*). Cara is a major source of calories in many parts of tropical Africa and Latin America, with world production estimated at 20–22 million tons/year (1). Although raw cara flour has been used in breadmaking, many bakers consider its flavor to be less desirable than that of the pregelatinized product.

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MATERIAL AND METHODS

Preparation of Pregelatinized Cara Flour

Cara tubers (80% moisture) were placed in a wooden rotary drum peeler, with the speed adjusted so that friction between the tubers and the inside walls was adequate to remove the skin efficiently. A continuous stream of water was used to remove the skin from the peeler. After washing, the tubers were ground into a fine suspension that was boiled for 50 min. The suspension was cooled and spray-dried into flour (7.1% protein [N × 5.7], 0.5% lipids, 3.0% ash, and 94.7% carbohydrates db; 10.2% moisture) in a pilot spray drier (Niro Atomizer with gas-fired air heater system and centrifugal atomizer).

Wheat Flour

The wheat flour was an unmalted, unbleached straight-grade variety milled from Brazilian-grown wheat on a commercial roller mill (protein content 10.65 [N × 5.7], ash 0.53% on 14% mb).

Evaluation of Rheological Properties

The rheological properties of cara-wheat flour mixtures were determined by the standard flour-water dough (FWD) system (2), and by the bread dough (BD) system when the baking ingredients were added.

Properties of FWD. The mixing and load extension properties of mixtures of wheat flour with 2.5% increments of pregelatinized cara flour (0–15% on flour

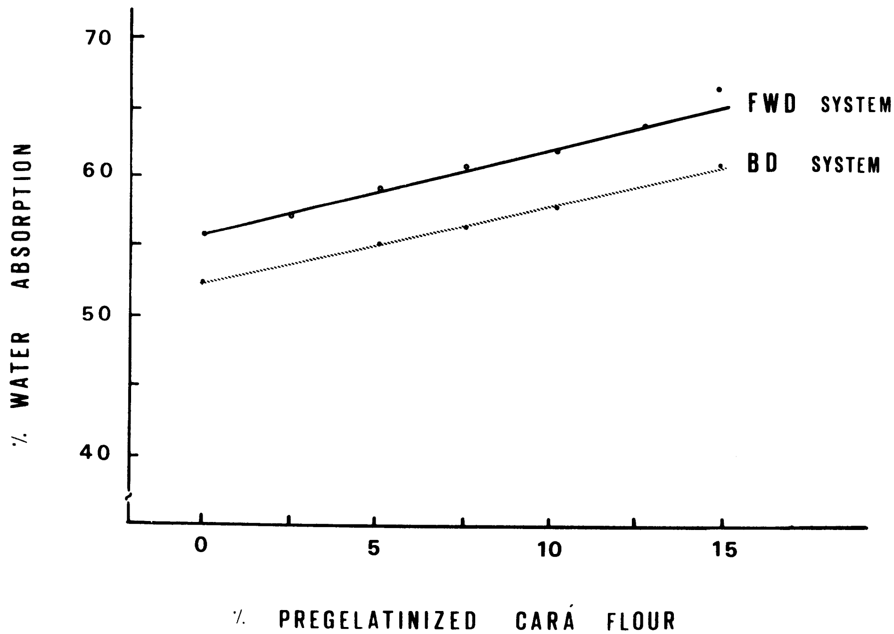

Fig. 1. Water absorption of wheat-pregelatinized cara flour mixtures in flour-water dough (FWD) and bread dough (BD) systems.

basis) were evaluated; levels of cara greater than 15.0% were found to be difficult to handle, and the experiment was discontinued at that level. The mixing properties of the dough were determined with the Brabender Farinograph using the constant flour weight method (2). The load extension curve was determined by the Brabender Extensigraph method (2).

Properties of Bread Dough. Bread dough was prepared as El-Dash (3) described. Samples of 300 g of the pregelatinized cara-wheat flour mixtures (14% mb) were placed in the 300-g farinograph bowl and mixed for 5 min until the temperature of the flour reached that of the mixer (30° C). The buret was filled with water at 30°C; salt (1.75%) and sucrose (5%) were dissolved in approximately 50 ml of the water, while yeast (3%) and ascorbic acid (90 ppm) were mixed in another approximately 50 ml of the water. The ingredients were added to the flour along with the predetermined amount of distilled water at 30° C—enough to center the curve at a consistency of 500 farinograph units (FU); 3% hydrogenated shortening was added. Addition of all ingredients was completed within 30 sec. After the dough was mixed to the test time (test optimum mixing time), which is the minutes of mixing needed for the dough to show a drop of 10 FU from the maximum consistency, the farinograph was

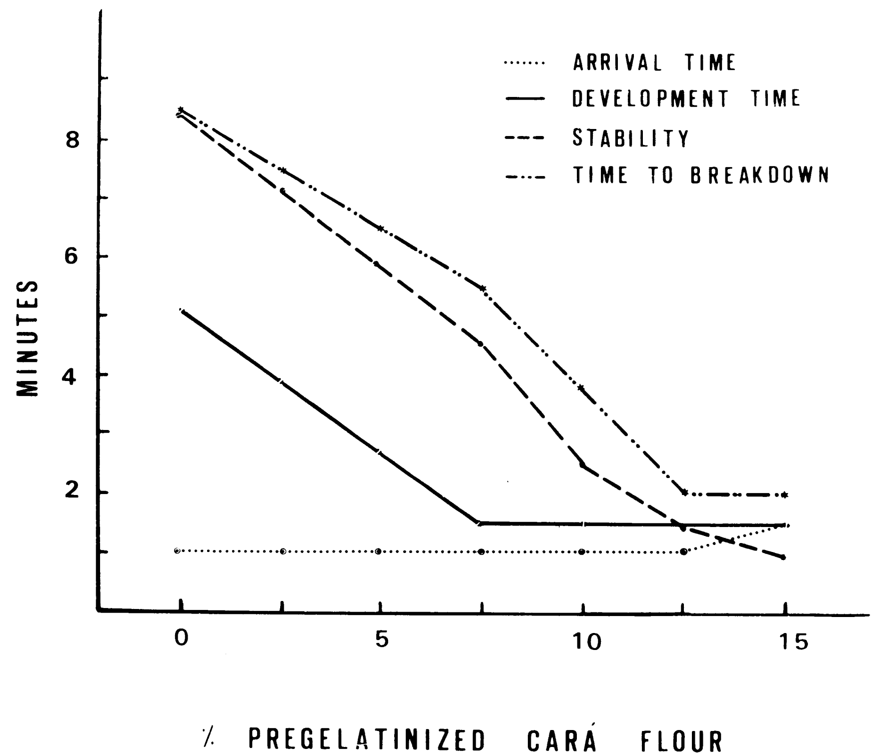

Fig. 2. Effect of pregelatinized cara flour on mixing properties of dough in flour-water dough system.

stopped and two pieces of dough (150 g $\pm$ 0.1 g) were rounded and molded using the extensigraph; these were then placed in the fermentation cabinet of the extensigraph. After 45, 90, and 135 min of fermentation, the load extension curve was determined. Each experiment was repeated twice, resulting in four separate measurements for each flour.

Determination of Pasting Properties. Pasting properties of wheat flour and wheat flour-pregelatinized cara flour mixtures were investigated with the Brabender Viscoamylograph. An 80-g sample (14% mb) was suspended in 450 ml of distilled water; the suspension was then poured into the viscoamylograph bowl and the speed adjusted to 75 rpm. The suspension was heated at the rate of 1.5°C/min to 95°C, where it was maintained for 20 min and then cooled to 50°C. Pasting temperature, peak viscosity, and viscosity at 50°C (cooling cycle) were recorded (4).

Baking Test

The baking quality of wheat flour and wheat flour mixed with 5, 7.5, 10, and 15% pregelatinized cara flour (on flour basis) was determined according to the method of El-Dash (3) as follows:

Flour (14% mb)	100%	300 g
Salt (99.5% purity)	1.75%	5.25 g
Sucrose	5%	15 g
Fresh compressed yeast	3%	9 g
Hydrogenated shortening	3%	9 g
L-ascorbic acid	90 ppm	27 mg

The bread dough was mixed in the farinograph mixing bowl as described above. The dough consistency was 500 FU, except for some experiments with 15% pregelatinized cara flour in which consistency was adjusted to 600 FU. The mixing temperature was 30°C, and mixing speed 63 rpm. After the dough was mixed to test optimum mixing time, two 150-g pieces were immediately scaled off, rounded and molded in the extensigraph, and placed in baking pans (top, 14 $\times$ 6.8 cm; bottom, 13 $\times$ 5.5 cm; depth, 4.2 cm) for fermentation of 105 min at 30°C. The loaves were baked for 20 min at 220°C. The test was repeated three times, providing six loaves for each flour in question.

Evaluation of Bread Quality

The loaf volume was determined by seed displacement within 1 hr after the bread came out of the oven, and a volume score was determined by multiplying the specific volume by 3.33 to allot the maximum of 20 points for a loaf of bread with a specific volume of 6, which was considered optimum. The bread quality was then evaluated by a panel of five trained personnel, who scored the bread according to the following scale: crust color and characteristics, 15 points; break and shred, 5 points; symmetry, 5 points; crumb color, grain, and texture, 10 points each; aroma and taste, 25 points.

RESULTS AND DISCUSSION

Cara flour is composed basically of starch, and numerous authors (4–8) have cited the importance of starch in dough and bread quality. Alsberg (6) attributes the role of starch in breadmaking to its effect on water absorption, dough consistency, and viscosity, while Medcalf (4,8) indicates that the importance of starch is due to its governing the rheological properties of dough. The maximum level of pregelatinized cara flour, which can be incorporated with wheat flour, must therefore be determined not only by its effect on the baking quality of the bread produced but also by its effect on the physical properties of dough. The latter should be determined in a BD system. In such a system, all the ingredients normally used in baking are incorporated, making it possible to account for their collective effect. It thus provides a test of dough characteristics under more realistic conditions than does the commonly used FWD system, as bakers seldom use a simple FWD for production of bread.

Effect on Water Absorption

The water absorption of different mixtures of wheat flour with pregelatinized cara flour is presented in Fig. 1. The addition of pregelatinized cara flour caused an increase in water absorption at all levels tested, but the water absorption determined by the normal farinograph procedure (FWD system) exhibited higher values than did those determined by the BD system, even though the consistency of the dough in both cases was 500 FU. Specific water absorption in the FWD and BD systems was 0.56 and 0.52 ml/g for wheat flour and 1.13 and 0.91 ml/g for pregelatinized cara flour. This indicates that the presence of the

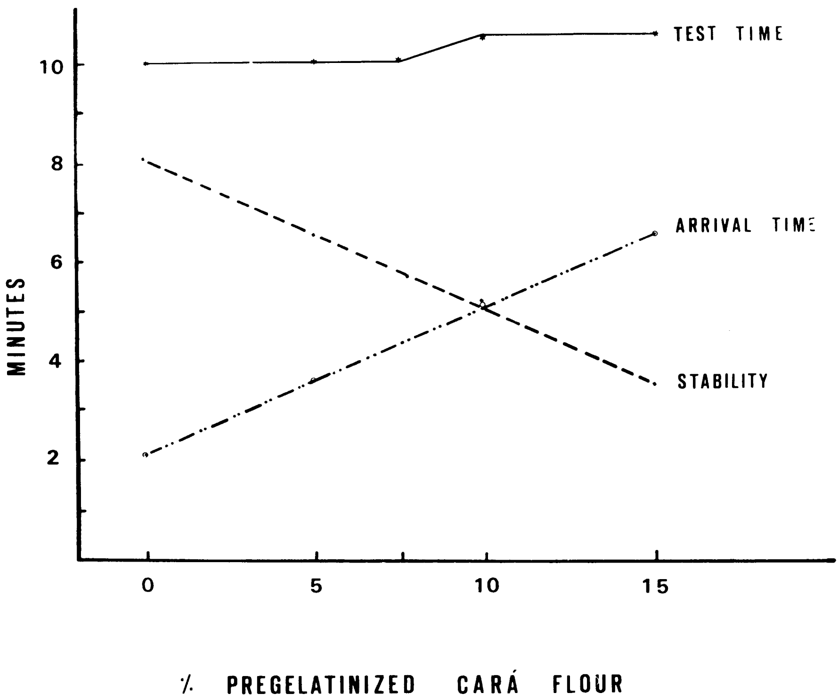

Fig. 3. Effect of pregelatinized cara flour on mixing properties of dough in bread dough system.

other baking ingredients causes a reduction in water absorption capacity of both wheat and pregelatinized cara flour. The specific absorption of pregelatinized cara flour (1.13 ml/g) is much higher than that of wheat flour (0.56 ml/g) and wheat starch (0.44 ml/g), although it is lower than that reported for damaged wheat starch (2 ml/g) (9).

Effect on Mixing Properties of Dough

The effect of the pregelatinized cara flour on mixing properties in the standard FWD system is presented in Fig. 2. A sharp drop was observed in dough development time with addition of cara flour; it dropped to a minimum of 1.5 min with the addition of 7.5% cara flour and then remained constant for levels up to 15%. The stability also decreased at all tested levels of cara. Breakdown time also showed a sharp decrease, exhibiting a maximum weakening effect at the 12.5% level. The results obtained here suggest that the mixing of such a dough in commercial baking would be critical.

When testing the mixing requirements and dough stability using the BD system (Fig. 3), however, the mixing properties of the BD system were observed to be different from those obtained with the standard FWD system. While the arrival time increased linearly in proportion to the quantity of pregelatinized cara flour, the test time (test optimum mixing time) remained essentially constant up to 7.5% (10 min) and was only 10.5 min at the 15% level of cara flour. Although the dough stability decreased proportionally, the dough was much more stable in the presence of the other bread ingredients, thus decreasing the risk of overmixing in commercial baking.

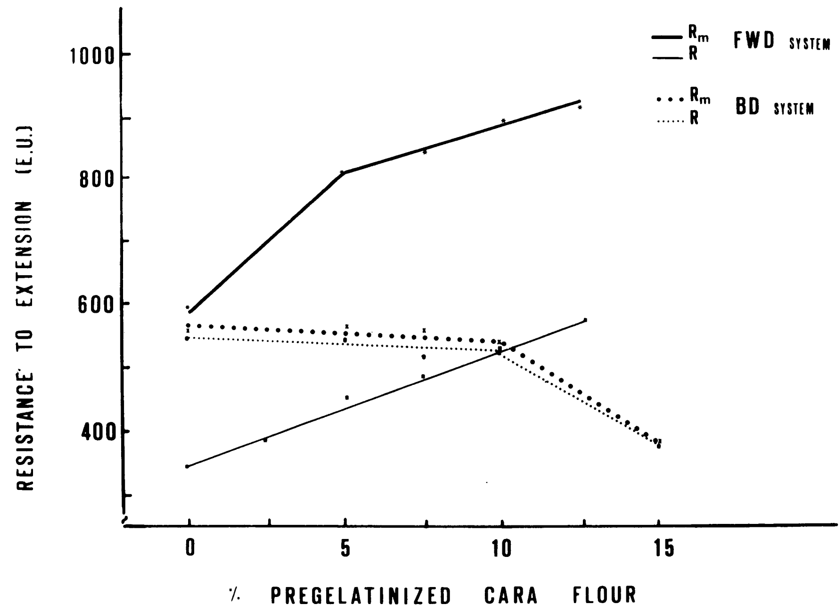

Fig. 4. Effect of pregelatinized cara flour on resistance to extension of dough in flour-water dough (FWD) and bread dough (BD) systems.

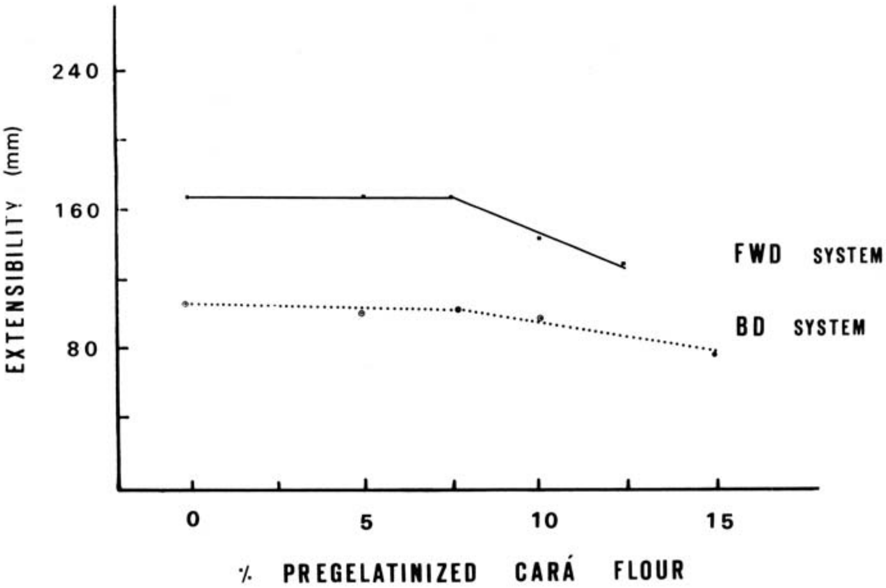

Fig. 5. Effect of pregelatinized cara flour on extensibility in flour-water dough (FWD) and bread dough (BD) systems.

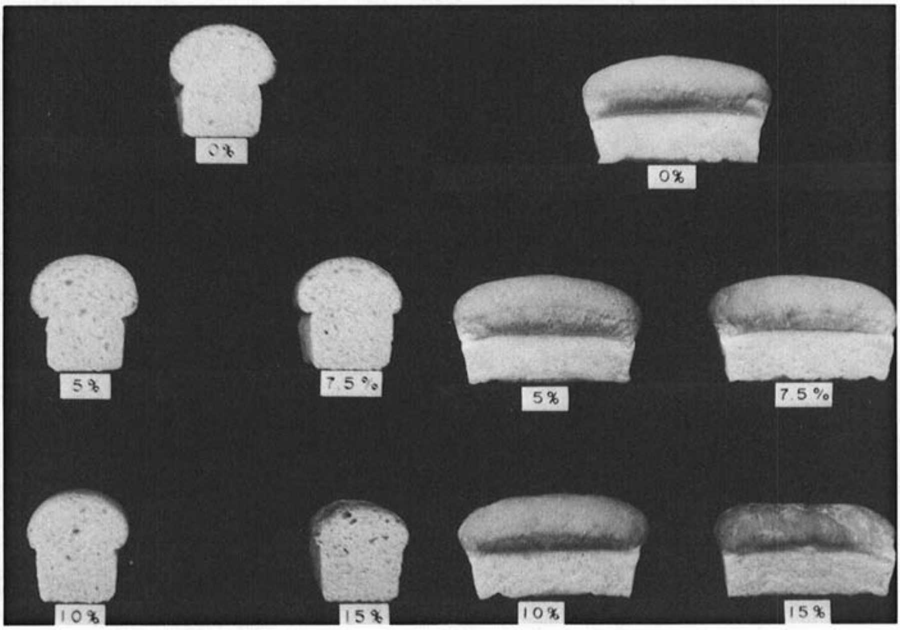

Fig. 6. External and internal characteristics of bread made with various levels of pregelatinized cara flour.

Effect on Load Extension Properties of Dough

At 135 min of rest time (Fig. 4), the extension properties of dough (FWD system) showed an increase in both resistance (R) and maximum resistance to extension (R_m) on increasing the level of pregelatinized cara flour. This strengthening effect suggests the presence of an oxidation factor in pregelatinized

TABLE I
Effect of Pregelatinized Cara Flour on Pasting Characteristics

	Percentage of Pregelatinized Cara Flour				
Pasting Characteristic	**0**	**10**	**20**	**30**	**40**
Pasting temperature (°C)	61.5	61.5	61.5	61.5	64.5
Temperature at maximum viscosity (°C)	93.0	93.0	93.0	93.5	95.0
Maximum viscosity (AU)[a]	890.0	840.0	720.0	510.0	430.0
Minimum viscosity (AU)	470.0	450.0	420.0	320.0	280.0
Viscosity at 50°C (cooling cycle)	1,000.0	1,000.0	900.0	760.0	540.0

[a]AU = amylograph units.

TABLE II
Quality Evaluation of Bread Made With Different Percentages of Pregelatinized Cara Flour

Bread Quality	Percentage of Pregelatinized Cara Flour				
Score	**0**	**5**	**7.5**	**10**	**15**
Specific Volume	**4.68**	**4.91**	**4.73**	**4.06**	**3.48**
Volume[a] (max 20)	15.6	16.2	15.6	13.4	11.5
External characteristics (max 20)	15.0	17.0	16.5	12.5	7.5
Internal characteristics (max 35)	27.0	28.5	30.0	26.0	21.0
Taste and aroma (max 25)	20.0	21.0	22.0	20.0	18.0
Total score (max 100)	77.6	82.7	84.1	71.9	58.0

[a]Volume score = specific volume × 3.33.

cara flour.

On testing the dough in a BD system in the presence of the other baking ingredients, however, no similar effect was observed; both the R and R_m remained essentially constant and even showed a sharp drop above the 10% level. Thus, in the presence of all of the baking ingredients, more than 10% of pregelatinized cara flour seemingly could result in a serious reduction in physical properties of dough. The difference between R and R_m was pronounced in the FWD system, but was fairly small in the BD system; extensibility of dough in the BD system was also much lower than that in the FWD system (Fig. 5). The discrepancy in the results obtained from the use of the FWD system and a BD system suggest the need to test the performance of any composite flour dough in a BD system to permit measuring and accounting for the collective effect of all of the baking ingredients.

Effect on Flour Pasting Properties

The effect of pregelatinized cara flour at 0, 10, 20, 30, and 40% levels on the pasting properties of wheat flour are presented in Table I. The flour had a low α-amylase content, as was evident in the high maximum viscosity. Pregelatinized cara flour up to the 20% level caused only a slight change in maximum viscosity or viscosity at 50°C; however, higher levels caused a distinct reduction of viscosity.

Effect on Bread Quality

Bread made from doughs with different proportions of wheat and cara flour are shown in Fig. 6. The quality scores of such bread are presented in Table II. A

TABLE III
Effect of Calcium Stearyl-2-Lactylate and Dough Consistency on Bread Quality

	Percentage of Pregelatinized Cara Flour				
	10			15	
	Percentage of CSL Added			Dough Consistency (FU)	
	0	0.25	0.50	500	600
Specific Volume	**4.06**	**4.67**	**4.91**	**3.48**	**3.78**
Volume (max 20)	13.4	15.4	16.2	11.5	12.5
External characteristics (max 20)	12.5	16.5	16.5	7.5	11.0
Internal characteristics (max 35)	26.0	28.5	29.5	21.0	21.0
Taste and aroma (max 25)	20.0	20.0	20.0	18.0	18.0
Total score (max 100)	71.9	80.4	82.2	58.0	62.5

slight improvement of bread quality was observed up to the 7.5% level due to a slight improvement in both external and internal characteristics, including the specific loaf volume, but with higher levels, a sharp decrease in quality was obtained.

Addition of calcium stearyl-2-lactylate (CSL) with a 10% level of cara improved loaf volume (specific volume increased from 4 to 4.66) and improved the external and internal characteristics of the bread (Table III). Increasing the level of CSL from 0.25 to 0.5%, however, produced no proportional increase in quality. Although the specific volume did increase slightly to 4.86, the other characteristics remained essentially the same.

Since the handling properties of dough (500 FU) with more than 10% cara were difficult, an attempt was made to improve the handling properties by increasing the bread dough consistency to 600 FU. When using 15% cara flour under these conditions, a reduction in water absorption from 60.8 to 57.3% (BD system) was observed. Although the handling properties of the dough were enhanced, the quality of the bread showed only a slight improvement (Table III).

Under test conditions with medium strength flour, up to 7.5% of pregelatinized cara flour can be used without the need for special additives. If 0.25% CSL is incorporated in the formula, up to 10% can be used with a dough of 500-FU consistency without a deleterious effect on bread quality. Increasing the consistency to 600 FU improves the handling properties of the dough, thus enabling the incorporation of 15% cara flour, but the bread quality will be reduced.

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