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The Use of Cassava Starch in Breadmaking*

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Canadian western red spring wheat (CWRSW) gluten was used in a composite flour formula of 85% starch and 15% vital gluten to assess the feasibility of using cassava starch in breadmaking. Some cassava starch technological properties, such as size, swelling power and gelatinization, were close to those of wheat starch, whereas amylose solubility and extent of retrogradation differed. The former property had a beneficial effect on starch gluten affinity while the latter had to be rectified by forming starch clathrate compounds with α-ctrystallinity forms of C_{16}-type monoglycerides. The study showed that wheat starch can be interchanged with cassava starch, retaining bread quality close to that of true wheat bread. This study is a contribution to the trend in the developing world to adopt composite flour technology.

INTRODUCTION

Wheat bread is a staple food in many countries. However, in the developing world wheat production is generally low and must be supplemented by expensive imports. The problem may be partially alleviated by adopting composite flour technology, which offers a means for extended utilization of the limited wheat supply in breadmaking.

This study investigated the possibility of using tropical root starches in making bread with organoleptic properties close to that of a true wheat bread. While arrowroot, taro, yam, sweet potato and cassava were studied, only the results of cassava will be presented. The starch and gluten of cv. Neepawa, a breadmaking quality western red spring wheat (CWRSW), was selected for the model study. A comparison of starch properties will be given first. This will include starch granule size distribution and morphology, swelling power and solubility, gelatinization behavior, retrogradation extent as a function of time, complexing with monoglycerides, and starch affinity for gluten.

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* Dedicated to Professor Mihailo Lj. Mihailović on the occassion of his 60th birthday.

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The starch study is followed by determination of composite flour dough rheological characteristics and evaluation of baked bread for its shelf-life and organoleptic properties.

MATERIALS AND METHODS

Starch. Cassava was isolated from Kenyan cassava root (*Manihot ultisima*) by a sedimentation process; wheat starch was isolated from cv. Neepawa wheat flour milled by a Buehler mill. The starch removed by dough washing was collected as recommended by the AACC method.

Vital gluten. It was obtained commercially from CWRSW Neepawa and consisted of 80% protein, 4.5% carbohydrates, 1.0% fat, 1% ash and 6.5% moisture.

Monoglycerides. C_{16}-type distilled monoglycerides of 90% purity were prepared on a large scale from hydrogenated palm oil by a palmitic acid enrichment process. The C_{18}-type was kindly donated by Vauxhall Foods Ltd., Vauxhall, Alberta, Canada.

Microscopic study of starch. Light microscopy was used for starch size distribution and scanning electron microscopy (SEM) for morphological study after starch sputter-coating with 20 nm gold. Photomicrographs were taken by a Cambridge Stereoscan model 150 at an acceleration potential of 15 kV. Dough and crumb internal structures were viewed by transmission electron microscopy (TEM), for which samples were fixed in glutaraldehyde, postfixed in osmium tetroxide and imbedded in araldite 502 resin. A Phillips type E-200 TEM was used.

Starch amylose content was determined potentiometrically with iodine[1] and starch mineral content by wet digestion.

Starch swelling and solubility methods were described earlier[2] as were viscosity and gelatinization properties using differential scanning calorimetry.[3,4] X-ray diffraction analysis was performed with copper Kα-radiation (1.5418 Å) at a scanning angular velocity of 1° (2Θ), using a time constant of 4 s.

Starch complexing with C_{16}- and C_{18}-monoglycerides in their α- and β-crystallinity forms was followed by determination of amylose complexing index as applied by Gilbert and Spragg.[5] The method of Dahle[6] was used to determine starch affinity for gluten.

Composite flour water absorption and rheological properties of the dough were followed using a Brabender farinograph with a 50 g mixing chamber with flours consisting of 85% starch and 15% vital gluten containing 3% yeast.

Dough preparation and baking followed a straight dough method: fermentation for 1.5 h, punch, rolling and pan proofing for 30 min, and baking at 210 °C for 30 min.

The fractional volume increase from dough to bread was calculated using the rape displacement technique. Dough and crumb hydration capacities were determined by the method of Dennett and Sterling.[7] Bread staling was followed by crumb compressibility, penetration resistance to a standard probe and X-ray diffraction analysis.

Bread quality evaluation was performed by a trained student panel using the AIB method for bread quality scoring.

RESULTS AND DISCUSSION

Particle size distribution of starch granules for wheat (cassava) showed that 36(10%) of the granules were below 5 μm in size, 40(49%) in the 5—10 μm size range, 12(9%) 16—20 μm and 6(1%) 21—25 μm. Larger granules were not found.

Morphologically, wheat starches were small platelets, donut-like or lenticular in shape. The majority of the larger granules had a distinct equatorial groove (Figure 1). Cassava starch granules were rather truncated, with a concave surface and a sharp sunken central point. Compounded granules were also observed (Figure 2).

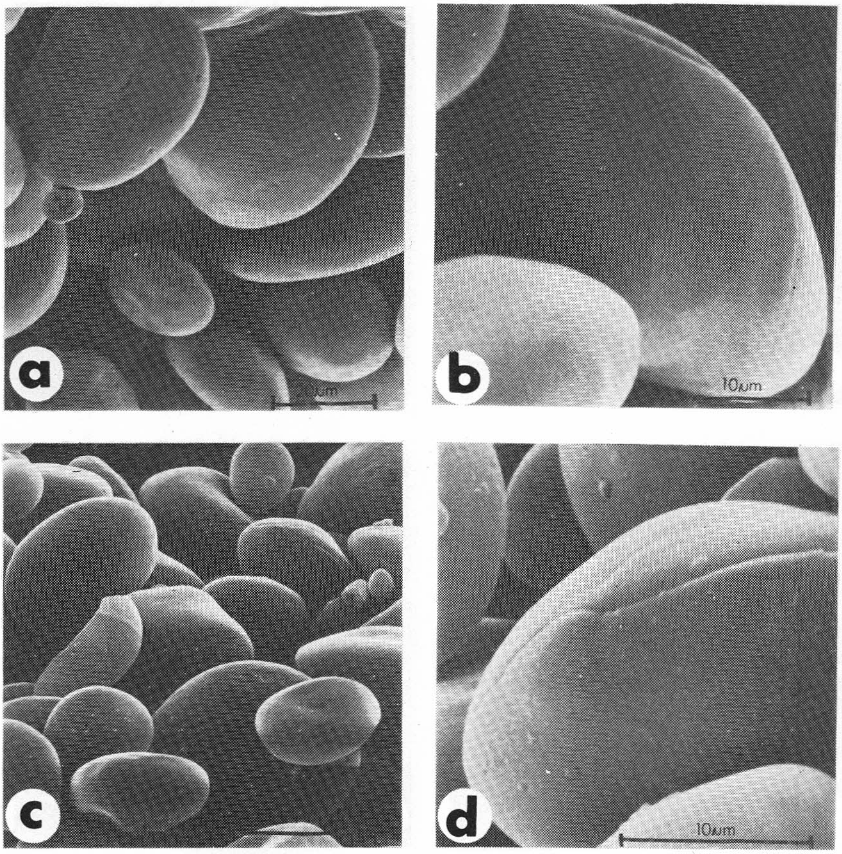

Figure 1. Scanning Electron Micrographs of Wheat Starches, cv. Fielder (a, x 1,120; b x 2,600); and cv. Neepawa (c, x 1,300; d, x 2,630).

Wheat starch contained 27.3 ± 1.5% amylose, and cassava only 21.0 ± ± 0.7%. Both starches had negligible amounts of minerals. The P content of wheat starch was 0.013 ± 0.006% and 0.0106 ± 0.0008% for cassava starch, but was 0.05% for wheat when the lysolecithin removal step, using water--saturated butanol, was omitted.

Swelling power (SP) of starch as a function of temperature (Table I) reveals that cassava has the highest SP at all temperatures, whereas wheat has low SP even above 75 °C.

The determination of amylose leaching during starch swelling strongly suggested that it is dependent on SP. Cassava had the highest solubility at all temperatures. Wheat starch solubility increased only above 80 °C, equaling that of cassava only at 95 °C.

Gelatinization thermogram (»G«) for both starches showed a dependence on water volume fraction in a range of $V_1 = 0.3$ to 0.8. Thus, at $V_1 = 0.7$ the onset temperature for wheat (cassava) was 50.0 °C (53.2), the peak temperature 55.2 °C (58.8) and the end of gelatinization 60.9 °C (66.4). The enthalpy of

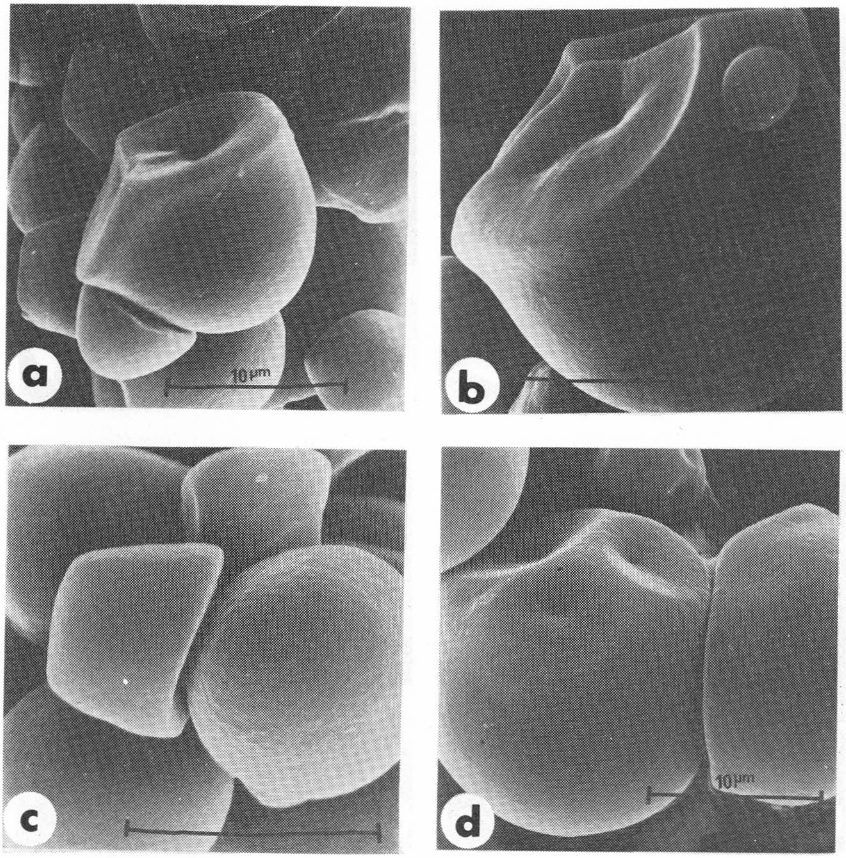

Figure 2. Scanning Electron Micrographs of Cassava Starches of (a) Commercial (A. E. Staley Manuf. Co., Decatur, IL.), (b) Fijian and (c) Kenyan Origins with Magnification Range of x 2,000 — x 2,500.

fusion (ΔH/cal/g) was 0.66 ± 0.10 (49 ± 0.05). At lower water volume fractions, M_1 crystallite endotherms appear, and are more pronounced with cassava starch. The presence of a starch-lipid chlathrate, which is present in wheat but not in root starches, was readily revealed by the M_2 crystallite endotherm. These melting characteristcs, as a function of water volume fractions, are summarized in Table II.

The M_1-onset peak and end of gelatinization temperature were irregular and not as well defined a for the G-endotherm. The former transition at higher temperature results from melting crystallites within a spherulite entity. The G-transition involves swelling of the amorphous regions of the spherulites by water stripping the starch molecules from the crystallite surface and denaturing and hydrating the starch. For both of these two distinct mechanisms for phase transition of starch granules of wheat and cassava, it appears that the G-transition mechanism is predominant.

TABLE I

Swelling Power and Solubilities of Wheat and Cassava Starches

Types of Starch	Temperature, °C							
	60	65	70	75	80	85	90	95
				Swelling Power				
Neepawa (HRSW)*	7.12 ± 0.45	10.00 ± 0.99	10.50 ± 1.15	9.71 ± 0.98	11.44 ± 2.00	12.43 ± 1.40	15.04 ± 2.0	18.83 ± 1.89
Kenyan cv. Cassava	15.57 ± 1.76	19.66 ± 1.06	22.45 ± 1.06	29.24 ± 0.80	34.50 ± 2.00	47.45 ± 3.62	66.77 ± 2.80	73.43 ± 4.17
				Solubilities				
Neepawa (HRSW)*	2.07 ± 0.30	1.98 ± 0.09	3.20 ± 0.20	3.55 ± 0.68	5.59 ± 0.34	9.88 ± 0.17	18.91 ± 0.76	28.56 ± 0.51
Kenyan cv. Cassava	3.31 ± 0.29	7.16 ± 0.52	6.92 ± 0.29	10.05 ± 0.46	14.96 ± 1.76	20.34 ± 1.33	31.14 ± 0.85	30.36 ± 0.66

* Hard red spring wheat — Western Canada.

TABLE II

Gelatinization Characteristics of Wheat and Cassava Starches

Type of Starch	Endotherms								
	Gelatinization (G)				Crystallite (M_1)				
	Volume Fraction	t °C Onset	t °C Peak	t °C End	ΔH/Cal/g*	t °C Onset	t °C Peak	t °C End	ΔH/Cal/g*
Wheat:	0.8	51.0	56.1	62.0	0.410	—	—	—	—
cv. Neepawa	0.7	50.1	55.4	61.2	0.200	62.8 ± 0.4	75.5 ± 5.0	83.0 ± 0.6	0.110 ± 0.050
	0.6	49.6	56.4	62.2	0.590	65.3 ± 0.4	77.8 ± 0.35	91.8 ± 1.8	0.180 ± 0.040
	0.5	50.5	56.0	58.6	0.220	73.5 ± 1.4	84.1 ± 2.6	101.0 ± 3.3	0.210 ± 0.020
	0.4	47.8	52.3	58.8	0.05	84.0 ± 7.8	102.3 ± 1.1	112.3 ± 2.5	0.260 ± 0.030
Cassava (Kenyan cv.)	0.8	52.9	60.8	71.3	4.59	—	—	—	—
	0.7	53.4	58.3	65.3	4.90	67.0 ± 0.7	75.8 ± 0.4	80.8 ± 0.4	0.79 ± 0.05
	0.6	52.3	58.3	64.0	3.75	70.8 ± 0.4	82.3 ± 6.7	89.3 ± 5.3	4.20 ± 0.09
	0.5	52.0	58.0	65.0	2.38	74.0 ± 1.4	88.5 ± 4.2	96.6 ± 4.1	1.89 ± 0.03
	0.4	54.5	65.8	77.0	2.09	80.3 ± 3.9	106.3 ± 6.0	124.8 ± 0.4	7.54 ± 0.07

* Enthalpy.

Retrogradation of 60% aqueous starch gels by aging (a molecular realignment from a randomly-coiled conformation) was also followed by differential scanning calorimetry. Wheat starch revealed a retrogradation endotherm only after 6 days of aging at 24 °C, while cassava developed an endotherm at 50 to 60 °C after 48 h of aging. This retrogradation trend was also revealed by X-ray diffraction patterns: they became sharper and better defined with starch aging. These results for staling of wheat starch gels differ from those measured by DTA and reported earlier.[8]

Crystallographic data for different polymorphic C_{16}-type 1-monoglycerides are provided in Table III.

TABLE III

X-Ray Diffraction Patterns of α- and β-Crystallinity Forms of C_{16} Monoglycerides

α-C_{16} Monoglyceride			β-C_{16} Monoglyceride		
2Θ, °	d, Å	Intensity cps	2Θ, °	d, Å	Intensity cps
6.048	14.6126	327	19.584	4.5327	2012
21.316	4.1682	1957	22.759	3.9070	1532
24.569	3.6233	338	26.475	3.3666	256
25.890	3.4413	329	28.692	3.1113	242

In this and following tables the diffraction line intensity
strong (s) > cps 400
medium (m) 200—399
weak (w) < 200

X-ray or infra-red spectra readily distinguished between these two forms.[4] The α-crystallinity form is invariably more reactive than β-form.[9] The starch complexing index increased from ungelatinized to gelatinized starches and for both starches was highest for solubilized or lintnerized starch forms. This strongly suggested that monoglyceride diffusion is involved, and is sterically inhibited by native starch granules. Some data for the α-crystallinity form are provided in Table IV.

TABLE IV

Complexing Indices (%) for the Interaction of the α-Crystallinity Form of C_{16}- and C_{18}-Monoglycerides With Cassava Starch

% MG	Cassava Starch					
	Ungelatinized		Gelatinized		Solubilized	
	C_{16}	C_{16}	C_{16}	C_{18}	C_{18}	C_{18}
0.1	4.75 ± 0.26	1.24 ± 0.22	11.69 ± 2.77	8.66 ± 0.38	28.72 ± 0.23	14.62 ± 0.80
0.2	6.24 ± 0.18	2.33 ± 0.06	24.09 ± 1.50	16.71 ± 2.89	47.93 ± 1.11	26.84 ± 0.19
0.3	7.58 ± 0.20	6.69 ± 0.91	38.07 ± 2.27	23.37 ± 2.31	58.02 ± 1.16	46.65 ± 2.47
0.4	9.67 ± 0.15	8.47 ± 0.06	43.31 ± 0.79	26.53 ± 0.80	63.30 ± 1.85	60.84 ± 1.51
0.5	9.97 ± 0.18	8.47 ± 0.11	46.19 ± 3.27	30.64 ± 0.08	70.73 ± 0.73	70.41 ± 1.37
0.8	11.05 ± 0.07	10.11 ± 0.56	4.09 ± 4.55	35.19 ± 0.49	78.76 ± 0.52	75.10 ± 1.70
1.0	12.09 ± 0.74	11.89 ± 0.30	49.24 ± 6.54	37.30 ± 0.47	83.12 ± 0.62	76.36 ± 2.86

Palmitic acid monoglyceride was more efficient in complex building than stearic acid monoglyceride, indicating that clathrate formation is dependent on fatty acid chain length. Optimum complexing was obtained at 0.5% monoglycerides (starch dry weight basis). Table V presents the affinity of starch for gluten in its gelatinized or nongelatinized forms in systems simulating the dough in its early and full-baked stages of breadmaking. Wheat starch had lower affinity for gluten in dough than did cassava starch. However, the affinity of wheat starch tripled in early baking but declined to about 1.5-times its initial value in fully-baked systems. Cassava affinity for gluten in dough doubled in early baking, equalling that of wheat, but also declined to its initial value at the fully-baked stage.

TABLE V

Starch Affinity for Gluten

Starch	Percent Affinity		
	Undenatured (Vital) Gluten		Denaturated Gluten
	+ Ungelatinized Starch (A)**	+ Gelatinized Starch (B)	+ Gelatinized Starch (C)
Wheat (cv. Neepawa)*	31.82 ± 3.99	88.61 ± 1.79	45.11 ± 0.78
Cassava	48.46 ± 7.46	82.05 ± 2.9	49.04 ± 2.99

* CWRSW — Canadian Western Red Spring Wheat
** A represents the dough, B the early baking, and C the fully baked stages of breadmaking.

The above results suggest both starches play a similar role in baking. Their hydration and swelling power appeared to be governed by the internal structure of the starch granules, such as number of micelles and their strength, rather than by repulsion forces imposed by ionized phosphate groups. The internal associations within the cassava starch granule are stronger than in wheat as the enthalpy results reveal, and strongly suggest, the involvement of the amylopectin moiety of the granules. When internal associations are disrupted by a »G« transition mechanism, cassava starts to predominate in swelling power and it also predominates in the extent of amylose leaching. As found by Dennett and Sterling,[7] starch amylose has a direct influence on the affinity of starch for gluten. Since affinity is a surface phenomenon, leached-out amylose from cassava has to be implicated. Our results support such an assumption. For both starches, the observed rise in affinity for gluten, at the early baking stage, also suggests that starch gelatinization and or swelling is a prerequisite for a substantial affinity increase.

These data indicated a possible interchange of wheat starch with that of cassava, without affecting the breadmaking process. However, the three-fold faster retrogradation rate for cassava starch also suggested that such bread, even after one day, might have an unacceptable staling property. However, it was found that the staling property can be readily avoided by clathrating cassava starch with reactive α-crystallinity-type C_{16}-monoglycerides. Complex

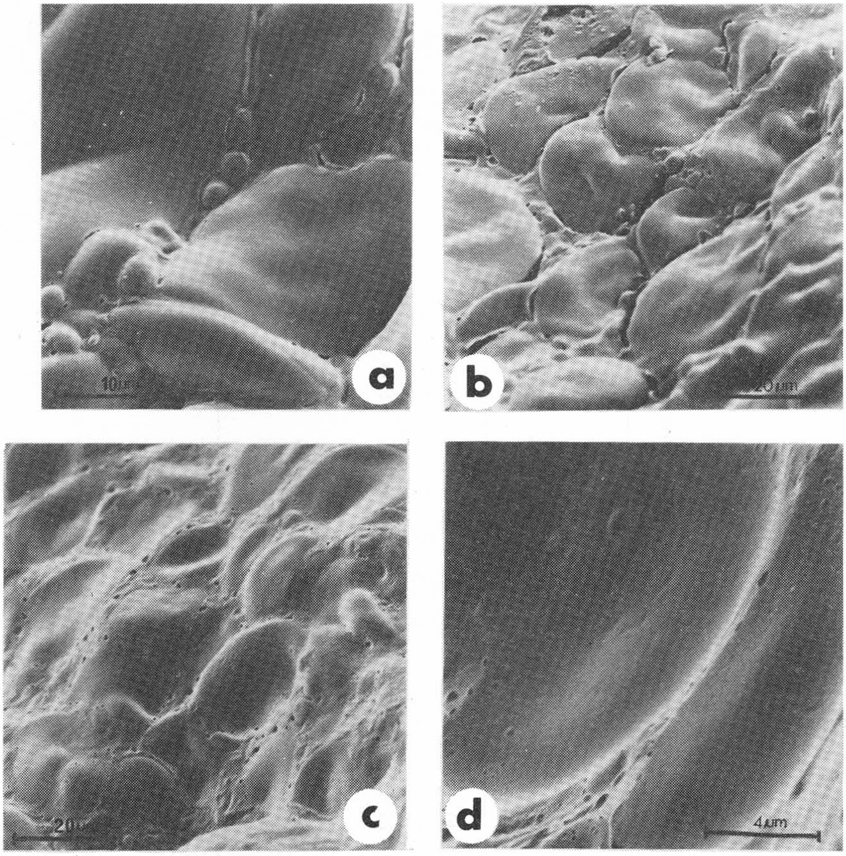

Figure 3. SE-Micrographs of Bread Crumb Surfaces of Wheat, cv. Neepawa Starch/ /Vital Gluten Composite — a, x 1,600; b, x 870; and its Flour — c, x 450; d, x 1,600.

indices show that cassava starch-lipid interaction can be increased up to fourfold once the starch granule is gelatinized, as occurs in breadmaking.

The possibility of interchanging wheat with cassava starch in bread was also supported by SEM (*e. g.* Figure 3) and TEM micrographs. They show that the majority of cassava starch granules were as well embedded in the gluten matrix as were wheat starch granules. On the other hand, there was a lack of mechanical damage to cassava starch granules, while the damage imposed by flour milling was about 8% in wheat starch, a damage required for any bread leavened by yeast. Hence, cassava dough formulations had to incorporate 7% sucrose as yeast food.

Based on these preliminary results, the similarity of wheat and cassava starch roles in bread dough development was not unexpected (Table VI).

There is a difference in dough development time, which is consistent with the fact that root starches in general require less time for dough development. Nevertheless, the dough stability results are similar. The only significant difference is the effect of starch on mixing tolerance. Cassava gluten matrix breaks down faster than that of wheat starch. This difference

TABLE VI

Farinographic Data of Wheat Flour and Cassava Flour Composites

Sample	Percent Moisture Content	Percent* Absorption	Arrival Time in Minutes	Peak Time in Minutes	Dough Stability in Minutes	Departure Time in Minutes	Mixing** Tolerance Index (MTI)	20 Min Drop
Neepawa Wheat flour	8.91 ± 0.13	68.40 ± 0.20	3.80 ± 0.15	6.00 ± 0.20	6.70 ± 0.10	10.50 ± 0.20	26.0 ± 5.0	45.0 ± 5.0
Neepawa Starch/gluten Flour composite	9.82 ± 0.38	60.40 ± 0.10	1.75 ± 0.10	6.50 ± 0.10	11.75 ± 0.15	13.50 ± 0.15	25.0 ± 3.0	45.0 ± 5.0
Cassava Starch/Gluten Flour composite	14.23 ± 0.41	64.70 ± 0.10	2.00 ± 0.16	4.50 ± 0.25	8.25 ± 0.20	10.25 ± 0.30	60.0 ± 0.7	130.0 ± 10.0

is further augmented by the drop over twenty minutes (expressed as Brabender units). The ability of wheat starch to support its own protein matrix after prolonged mixing is a unique inherent property of wheat starch and cannot be simulated by any root starch.

Dough baking results in profound changes. The vital gluten matrix is dehydrated and denatured. Its hydrophilic properties and affinity for starch are reduced. On the other hand, starch swells, absorbs water and gelatinizes. To quantitate the extent of cassava and wheat starch gelatinization, as induced by baking, their crumb hydration capacities were measured and related to that of dough. The difference should reflect the hydration due to the extent of gelatinization. These results are given in Table VII.

TABLE VII

Dough and Crumb Hydration Capacities (Water g/g Dry Solids)

	Dough**	Crumb	Gelatinization*** Hydration
Wheat flour, cv. Neepawa	0.061 ± 0.010	3.640 ± 0.060	3.579.0
Wheat starch cv. Neepawa + gluten*	0.125 ± 0.025	5.370 ± 0.120	5.245.0
Cassava starch + gluten	0.043 ± 0.004	6.600 ± 0.143	6.557.0

* Starch and vital gluten were used at 85% and 15%, respectively.
** Dough formulation: Flour 100% (or 85% starch + 15% vital gluten); sugar 7%; salt 1.5%; yeast 3.0%; water — variable to give doughs of same consistency.
*** Gelatinization hydration = crumb hydration capacity — dough hydration capacity.

The results confirmed that, during baking, cassava starch simulates and/or surpasses the gelatinization extent of wheat starch. This is unexpected since wheat starch enthalpy is much lower than that of cassava.

The volume change from dough to bread, expressed as fraction of the original dough volume ($V - V_o/V_o$ cm^3; V_o = dough volume, V = volume of bread) appears to be high, 1.49 ± 0.23 cm^3 for cassava. However, when specific volumes are calculated, the results are much closer: 2.94 ± 0.09 for wheat and 2.61 ± 0.21 for cassava.

What would a consumer's response be for a cassava-type bread? The sensory/organoleptic criteria of consumers cannot be ignored in food quality. Hence, a trained panel of graduate students was selected to perform the judging.

The panelists' mean and total scores for the external (total possible score 30) and internal properties of bread (maximum score 70) are given in Table VIII.

The analysis of variance of the quality of different bread loaves and the panelists' perception of the degree of difference between the various characteristics of breads are illustrated in Table IX for three sources of variation: color of crust, symmetry, and evenness of bake.

TABLE VIII

Bread Quality Evaluation†

Type of Bread	Panelists' Mean Scores***											
	Color of the Crust	Loaf Symmetry	Evenness of Bake	Break and Shred	Character of the Crust	Color of the Crumb	Grain	Aroma	Taste	Chewability	Texture	Total Score
Wheat												
cv. Neepawa Flour (maximum score)	8.00	3.00	3.00	3.00	3.00	10.00	10.00	10.00	15.00	10.00	15.00	90.00
cv. Neepawa*	5.75	1.98	1.92	1.92	2.40	9.66	9.28	5.42	12.07	7.82	13.69	71.91
Cassava*	4.25	1.88	1.38	1.75	1.71	7.61	9.17	8.92	9.49	5.29	9.17	60.62

† The score (10) for loaf volume not included.
* 85% starch and 15% vital gluten composites.
** SD = ± 0.10—0.20.
*** SD = ± 0.0—0.71.

TABLE IX

Analysis of Variance in Scores for Loaf Characteristics and Panelists' Perceptions of Characteristic Differences in Different Breads

Source of Variation		Sum of Squares	Degress of Freedom	Mean of Squares (Variance)	F Value		
					Calculated	95%	99%
1. Color of the crust:	Loaves	498.51	8	62.31	70.81	2.05	2.74
	Panelists	49.38	11	4.49	5.10	1.91	2.48
	Interaction	77.34	88	0.88			
2. Symmetry of form:	Loaves	59.99	8	7.50	19.32	2.05	2.74
	Panelists	10.27	11	0.93	2.40	1.91	2.48
	Interaction	34.16	88	0.39			
3. Evenness of bake:	Loaves	82.83	8	10.35	27.80	2.05	2.74
	Panelists	6.21	11	0.56	1.52	1.91	2.48
	Interaction	32.77	88	0.37			

TABLE X

Bread Quality Attributes Acceptability Rating in Percent

Type of Bread	Acceptability Mean Scores As Judged by the Taste Panelists										
	Color of the Crust	Loaf Symmetry	Evenness of Bake	Break and Shred	Character of the Crust	Color of the Crumb	Grain	Aroma	Taste	Chewability	Texture
Wheat:											
cv. Neepawa*	71.88	66.00	64.00	64.00	80.00	96.66	92.80	54.20	80.47	78.20	91.27
Cassava*	53.13	62.67	46.00	58.33	57.00	76.10	91.70	89.20	63.27	52.90	61.13

* 85% starch and 15% vital gluten composites.

TABLE XI

Bread Crumb Compressibilities of Wheat and Cassava Starch/Vital Gluten Composite Flours

Storage, Days	Neepawa Flour		Neepawa Starch/Gluten		Cassava	
	+ MG*	— MG	+ MG	— MG	+ MG	— MG
Fresh Bread (1/2 Day Old)	0.030 ± 0.004	0.060 ± 0.030	0.040 ± 0.006	0.050 ± 0.010	0.040 ± 0.010	0.100 ± 0.012
3	0.590 ± 0.080	0.620 ± 0.040	0.770 ± 0.090	0.800 ± 0.035	0.810 ± 0.070	1.290 ± 0.060
6	0.720 ± 0.060	0.750 ± 0.010	0.950 ± 0.007	1.020 ± 0.140	0.970 ± 0.050	1.300 ± 0.060
9	0.790 ± 0.060	0.930 ± 0.221	1.100 ± 0.040	1.270 ± 0.03	1.030 ± 0.090	1.320 ± 0.050

* MG, α-glycerol monopalmitate.
added (+) or omitted (—)

Insignificant variability is found for the panelists' ability to detect differences in the three sources of variation at both the 95 and 99% levels. The data in Table X show the acceptability rating versus bread quality attributes.

Cassava starch bread passed the rigorous organoleptic test. However, this was for freshly-baked bread. Additional data were required to judge bread keeping quality or shelf life. The cassava starch retrogradation property (partly reflected organoleptically by poor chewability) strongly suggested development of undesired firmness during bread storage. Crumb compressibility data proved this expectation. Cassava bread reached the firmness limit within a day, whereas wheat starch took 4 days. However, in the presence of only 0.5% monoglyceride, the shelf life was extended to 8 days for wheat and 9 days for cassava (compressibility limit 1,000 kg force/mm). Some quantitative data are provided in Table XI.
Of interest is the observation that root starch complexing with monoglycerides is invariably more pronounced than that of wheat.

The compressibility findings were strongly supported by crumb penetration resistance data.

The starch retrogradation mechanism involved in bread staling was additionally confirmed by analysis of starch isolated from crumbs. Diffraction line intensity and sharpness, especially at angles 17.075—17.781 and 19.361—20.07° (2Θ) clearly demonstrated that, in the absence of monoglycerides, cassava starch retrogrades better than wheat starch. However, these and other related data also suggest that crystallinity development with the gelatinized starch granule contributes less to crumb firming than does retrogradation of leached out amylose located in the intergranular gluten matrix of the bread crumb.

CONCLUSIONS

In conclusion, cassava proved to have real potential for use as a diluent of strong wheat flours or use along with vital gluten to provide acceptable, good quality composite bread. This finding should have an impact in countries where wheat availability is limited or where food products from root crops are already popular. Additionally, the model system study suggested that using cassava root flours instead of starch should also be feasible, since the flour is predominantly starch.

REFERENCES

1. T. J. Schoch, *Iodometric Determination of Amylose Potentiometric Titration: Standard Method.* In: *Methods in Carbohydrate Chemistry,* Vol. IV. p. 157. R. L. Whistler (ed), Acad. Press, N. Y., (1964).
2. I. Chung and D. Hadziyev, *Can. Inst. Food Sci. Technol. J.* **13** (1980) 143.
3. J. W. Donovan, *Biopolymers* **18** (1979) 263.
4. R. Hoover and D. Hadziyev, *Starch/Staerke* **33** (1981) 290.
5. G. A. Gilbert and S. P. Spragg, *Iodometric Determination of Amylose Iodine Sorption. Blue Value.* In: *Methods in Carbohydrate Chemistry,* Vol. IV, p. 68 (R. Y. Whistler, ed.). Academic Press, New York, (1964).
6. L. K. Dahle, *Wheat Protein-starch Interaction,* (E. F. Paschal, ed.), Academic Press, New York, (1971).
7. K. Dennett and C. Sterling, *Starch/Staerke* **31** (1979) 209.
8. K. H. Colwell, D. W. E. Axford, N. Chamberlain, and G. A. H. Elton, *J. Sci. Food Agric.* **20** (1969) 550.
9. N. Krog, *J. Amer. Oil Chem. Soc.* **54** (1977) 124.

SAŽETAK

Upotreba škroba kasave u pripravi kruha

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Ispitana su svojstva škroba cassave od važnosti za tehnologiju priprave kruha. Utvrđeno je da su neka svojstva kao npr. veličina, sposobnost bubrenja i gelatinizacije slična svojstvima pšeničnog škroba, dok se topljivost amiloze i raspon degradacije razlikuju od istih svojstava pšeničnog škroba. Kvaliteta kruha pripravljenog od miješanog brašna u kojemu je pšenični škrob zamijenjen škrobom cassave ne razlikuje se bitno od kvalitete kruha pripravljenog od čistoga pšeničnog brašna.