Emulsifiers and/or Extruded Starch in the Production of Breads from Cassava

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ABSTRACT

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A nutritious breadlike product can be prepared from cassava (*Manihot esculenta* Crantz) flour fortified with defatted soy flour (20%) by incorporation in the formula of either a viscosity-enhancing agent such as prehydrated extruded starch (12–15%) or surface-active materials such as self-emulsifying glyceryl monostearate (2–3%). The latter agent results in a greater air uptake at mixing, as exemplified by greater volumes at the end of the mixing stage, and both agents lead to improved gas retention during fermentation. Experimental data suggest that gas retention in the first phase of fermentation of cassava batters is influenced only to a small extent by the agents applied and that their action is based on a delay of the attainment of the critical buoyant size of the gas cells. Whereas the delay by the surface-active agent is based on the fact that more and smaller gas cells are formed during mixing, the effect of the pregelatinized material is due to a viscosity change, resulting in an increase of the critical buoyant size. During the baking phase, they influence the pasting properties of the starch and have a positive impact on the volume and crumb structure of the resulting products. Incorporation of surface-active material (4%) leads to a volume increase of 30%, whereas a much greater quantity of extruded starch (9–12%) is necessary to ensure a more modest volume increase (12%). At the same time, both the emulsifier and the extruded starch are responsible for good eating and keeping qualities.

Satin (1988) published an article that clearly shows how profound can be the impact for developing countries of the use of traditional crops for food purposes. Indeed, in those developing nations that virtually cannot grow wheat, wheat bread has become an attractive convenience food, although for obvious reasons indigenous crops would be preferable for the production of bread. Accordingly, much research has been undertaken over a number of years in an effort to bake bread from such crops. Although the work reported in the past is of high value, it has not had much practical implementation. Probably as a result, there has been less interest in such work in the past decade.

Recently, however, new efforts have been systematically undertaken, partly as a result of the ban on wheat imports by the Nigerian government. In general, there have been two approaches to this goal, corresponding to a partial or a total ban on wheat in the bread formula.

In the former case, a part of the wheat flour is replaced by other starch sources (De Ruiter 1978). Flours from millet and sorghum (Bushuk and Hulse 1974, Hanh and Rasper 1974), corn (Ballschmieter 1968, Bushuk and Hulse 1974), sweet potato (Hamed et al 1973), yam (Hanh and Rasper 1974, Ciacco and D'Appolonia 1978), and cassava (Kim and De Ruiter 1969, Dendy et al 1970, Hudson and Ogunsua 1976, Ciacco and D'Appolonia 1978) are among the most predominant studied for the production of composite-flour breads.

In the latter case, several approaches have been described in the literature, all aimed at substituting for the gluten properties in the final products. Indeed, wheat dough is viscous as well as elastic. Both rheological properties are attributed to gluten, and both are involved in the breadbaking potential of wheat.

Satin (1988) proposed baking bread from local crops by pregelatinizing a part of the flour or by using xanthan gum. Making bread from a source such as cassava requires, as the author states, that one find a good substitute for gluten, the essential requirement being "something that gives a stable but flexible cell wall to retain the bubbles of carbon dioxide produced by the yeast." Whether or not such a flexible cell wall is created is, however, not clear to us. The actions of viscosity enhancers such as pregelatinized flour (Kulp et al 1974, Satin 1988), xanthan gum (Christianson et al 1974, Ranhotra et al 1975, Satin 1988), or pentosans (Casier and De Paepe 1973) could well be different. Indeed, in an alternative interpretation, the increase in viscosity that results from the incorporation of such agents into the formula leads to improved gas retention, since the release of the leavening gas is controlled by diffusion (Hoseney 1984a,b).

It seemed important to us to study the potential application of extruded materials as viscosity-enhancing agents in the baking of cassava bread. To the best of our knowledge, the use of such materials for the production of wheatless bread has never been reported before.

Apart from the above studies, significant work was done by a Dutch team about two decades ago. Since the initial finding by Jongh (1961) that surface-active materials such as glyceryl monostearate (GMS) permit baking of starchy materials, significant work has been performed in this regard (Kim and De Ruiter 1968, 1969; Pringle et al 1969). Jongh (1961) found that, in the presence of surface-active agents, starch "breads" were softer because of a weaker binding of the gelatinized starch in such systems. In this work, the author did not systematically investigate the impact of surface-active agents. In later work, the impact of GMS on starch gelatinization was better understood in terms of adhesion to the starch surface and a consequent delay of the gelatinization process (Krog and Nybo Jensen 1970, Morad and D'Appolonia 1980, Eliasson 1986). This phenomenon might explain why the resulting products have improved volume. Strangely enough, in recent work, the potential of surface-active materials is not exploited, although the data available in the literature are (at least) promising. Other than that, we find that not much is recorded in the literature on the mechanisms by which they enhance the baking potential of starchy materials, although it seems rather obvious to us that, by their own nature, they reduce the interfacial tension and hence facilitate bubble formation.

The present work was undertaken to study the application of extruded starches and/or surface-active materials for the production of bread from cassava flour. To that end, we not only baked bread, but were equally interested in understanding the impact of the added materials on batter rheology and starch gelatinization.

MATERIALS AND METHODS

Materials

Purchased materials used were: self-emulsifying GMS (Tegin Spezial, Th. Goldschmidt AG, Essen, Germany), extruded corn starch (Cerestar AJ 11000, Cerestar, Vilvoorde, Belgium), native corn starch (Meritena, Amylum), defatted soy flour, (Soyamin 50-E, Lucas Meyer, Hamburg, Germany), shortening (Crisco, Procter and Gamble) and Fermipan (Gist-Brocades, Delft, The

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Netherlands). Tegin Spezial is a mixture of monoglycerides of palmitic and stearic acids, self-emulsifying because of the addition of traces of alkali stearates. It is characterized by a total monoester content of 40–48%, a hydrophile-lipophile balance value of 12, a saponification value within a 148–158 range, and a free glycerol content of 6–9%. The extruded corn starch had a solubility of 45, determined by gravimetric determination of the oven-dried (100° C) water-soluble fraction of 1 g (dry matter basis) of extruded material in 100 ml of water. Since cassava flour contains virtually no protein, soy flour was included to ensure a nutritionally balanced product. The soy flour had a protein content of 56.0, with a dispersibility index of 70–75% and carbohydrate, mineral, dietary fiber, and fat contents of 38.0, 6.0, 3.5, and less than 1.0%, respectively.

The cassava flour was obtained from the International Institute of Tropical Agriculture (Ibadan, Nigeria) courtesy of Gillian Eggleston. It was produced by washing and peeling unfermented tubers. The peeled tubers were washed again and chipped in a mechanical chipping machine. The chips were then dried in an oven (Gallenkamp 0V440) at 50–60° C for 24 hr. The dried chips were milled in a Wiley mill (model ED-5).

GMS for Bread from Cassava

GMS was added to the formula as an emulsion in water. To that end, the emulsifier (10 g) was added to water (90 cm^3, 70–80° C) under mechanical stirring (20 min, 70–80° C). The mixture was then cooled under mechanical stirring (20 min, room temperature).

Bread Recipe Development

At the onset of this work, we had no previous experience with the production of bread from cassava. Since we felt that variation of ingredients and processing conditions potentially could lead to interactions, we decided to optimize our bread baking method by applying response surface methodology rather than using a one-variable-at-a-time approach. The procedure employed was a factorial design with use of the center point, described by Box and Wilson (1951). More details of this preliminary work are described by Martens (1990) and Schellekens (1990).

Bread Production

A Kitchen Aid mixer (5K45SSAL) was used to make the batter. The ingredients were mixed dry for 1 min (speed 1) before GMS and/or prehydrated extruded corn starch and water were added. Where extruded starch was used, the quantity added replaced an equal quantity of cassava flour. Preliminary results suggested that problems arise when the extruded starch is added to the formula in a dry form. Indeed, the results of such experiments were found to lack reproducibility because of too high a degree of variation in the bread crumb structure. Prehydration of the starch (20% in water, w/w, room temperature) before mixing the batter solved this problem.

The batter itself was prepared with a flat beater working at high speed (No. 6) for 10 min. It was then poured into a Shogren-type baking pan (TMCO, National Manufacturing, Lincoln, NE) and fermented at 30° C (60 min, 90% relative humidity). The fermented batter was baked at 230° C for 30 min in a reel-type oven (TMCO). Loaf volumes were measured by rapeseed displacement 90 min after removal from the oven.

TABLE I
Ingredients for Cassava Bread

Ingredients	Amount (g)
Cassava (+ extruded starch)[a]	80.0
Glyceryl monostearate	0–4.0
Defatted soy flour[a]	20.0
Sugar	6.0
Salt	1.5
Yeast	1.5
Shortening	1.0
Water[b]	145

[a] 14% moisture basis.
[b] Includes the moisture in the cassava, defatted soy flour, glyceryl monostearate emulsion, and/or prehydrated material.

Gas Retention Capacity of a Batter

To investigate the gas retention capacity of bread formulas, half of the batter (prepared as outlined above) was poured into a graduated glass cylinder (500 ml, internal diameter 50 mm) in a water bath at 30° C. The volume of the fermenting batter was recorded at 5-min intervals for 120 min.

Consistency of Batters Prepared with Extruded Starch or GMS

Batters (without yeast) were prepared with and without 3% GMS or 12% extruded starch. A quantity of batter (25 g) was transferred to a mixograph bowl (10 g), and the sample was run for 8 min with the spring in position 1.

Pasting Properties of Batter and Bread Crumb

The Brabender Viscoamylograph was used to study the pasting properties of the bread crumb of formulas with and without extruded corn starch or GMS. Samples of bread crumb were collected 30 min after removal from the oven. To that end, the outer 0.5 cm of the bread was cut away. Bread crumb (55 g of dry matter) was blended in 450 ml of water, and the obtained mixture was poured into the amylograph bowl. The suspension was heated uniformly from 30 to 95° C, held at 95° C for 15 min, and then cooled uniformly to 50° C.

The pasting properties of selected unfermented and fermented batters were also studied. Batters were prepared as described above. A quantity of batter was weighed out such that the dry matter content was equal to that of the bread crumb used in the study of the pasting of bread crumb, and the analysis was performed with the same amount of water.

Bread Firmness Evaluation

Bread firmness was measured according to AACC method 74-09 (AACC 1983) with a universal testing machine (Wolpert TZM 771 10 KN). A 21-mm plunger was used as is described for 100-g pup loaves. Bread crust was not removed from the samples before the compression test was performed, and firmness readings were reported as the force (N) necessary to compress a slice (25 mm thick) by 25%. To test the effect of extruded corn starch and/or GMS on bread firming, loaves were stored at 21° C in a wooden cabinet. Measurements were made at 24-hr intervals for three days, after an initial storage of 10 hr after baking.

RESULTS AND DISCUSSION

Bread Recipe Development

In the early stages of this work, many discouraging results were obtained because many "breads" were produced that could never be considered edible. Also, we had introduced so many variables into the model that the response surface methodology procedure could not yield systematic results.

After analysis of the data, we retained only those ingredients that are listed in Table I and started all over again. Optimalization of the formulas was at that moment nothing more than getting away from low-volume, dense structures. The next step was aimed at obtaining volume increases as large as possible. After a significant series of baking trials, no more volume increases could be obtained by varying process parameters or recipe formulation. The third phase was consequently directed at obtaining better crumb structures. As a result of the formula optimalization we came up with the ingredient list and amounts shown in Table I.

Bread Baking

The effects of the incorporation of extruded starch (6.0, 9.0, 12.0, and 15.0%) or GMS (1.0, 2.0, 3.0, and 4.0%) on loaves were studied. Loaf weights and volumes are reported in Table II. These data clearly show that the surface-active agent applied in this work leads to greater volume increases than could be observed with the extruded material. Figure 1 shows bread crumb obtained with increasing amounts of extruded starch and GMS, respectively. The beneficial effect on crumb structure of increasing dosages of GMS can, to a certain degree, also be obtained by addition of prehydrated extruded starch. Indeed, replacing 0.0–15.0% of the cassava flour with such starch had an improving effect on the crumb structure, as demonstrated in Figure 1.

At the same time the bread crust became crumbly when 4.0% GMS was used. For this reason a dosage of 2–3% is recommended.

The importance of the extrusion (pregelatinization) of the starch source is illustrated in Figure 2. A formula incorporating 12% prehydrated extruded corn starch was compared with others in which the prehydrated extruded corn starch was replaced by prehydrated native corn starch or prehydrated cassava flour. Whereas no significant differences in loaf volumes were noted, crumb structures were more regular when the added starch had been pregelatinized.

Gas Retention Capacity of Batter

Batter volume increases recorded at 5-min intervals for formulas with and without 3% GMS or 12% extruded corn starch are shown in Figure 3. In contrast to the control, the batters containing extruded corn starch or GMS could be doubled in volume. This clearly shows that even during the fermentation phase the gas retention capacity of the batter (in glutenless systems) is improved both by viscosity enhancers and by surface-active agents.

The control batter used in the fermentation experiments had a volume of 95 cc at the beginning of the fermentation phase, whereas the corresponding figures for the doughs with GMS or extruded starch were 145 and 100 cm^3, respectively. This implies that the surface-active agent leads to a much increased air uptake during the mixing stage, as was to be expected.

If one assumes that the viscosity-enhancing agents have no impact on the number or the size of the gas cells at the end of the mixing stage, then it seems likely that their action is based on the influence that they exert on the tendency of the gas cells to rise out of the batter. Indeed, our data clearly show that the point at which a significant number of cells reach a critical buoyant size (Handleman et al 1961) is delayed, suggesting that under conditions of higher viscosity the critical buoyant size is increased.

In the application of GMS, similar effects are observed. By its own nature, the agent reduces the average bubble size and increases the number of bubbles. Therefore, the leavening gas moves in a greater number of smaller gas cells. Again, the net result is that the critical buoyant size of the average bubble is reached at a later stage, as was experimentally observed.

An additional experiment showed that native starch did not delay the attainment of the critical buoyant size of the gas cells, whereas the extruded material did.

TABLE II
Weights and Volumes of Loaves Prepared with Incorporation of Different Levels of Extruded Starch or Glyceryl Monostearate

Material Incorporated (%)	Weight (g)	Volume (cm^3)
Extruded starch		
0.0	189.5	447
6.0	192.0	473
9.0	193.1	502
12.0	194.0	501
15.0	194.0	485
Glyceryl monostearate		
0.0	189.5	447
1.0	194.6	458
2.0	195.3	478
3.0	199.3	515
4.0	199.8	583

Consistency of Batters Prepared with Extruded Starch or GMS

Mixograms of batters prepared with or without 3% GMS or 12% extruded corn starch are shown in Figure 4. As can be seen, both GMS and extruded corn starch enhance the consistency f the batter, but the effect is more pronounced when extruded orn starch is used. The results with regard to the impact of

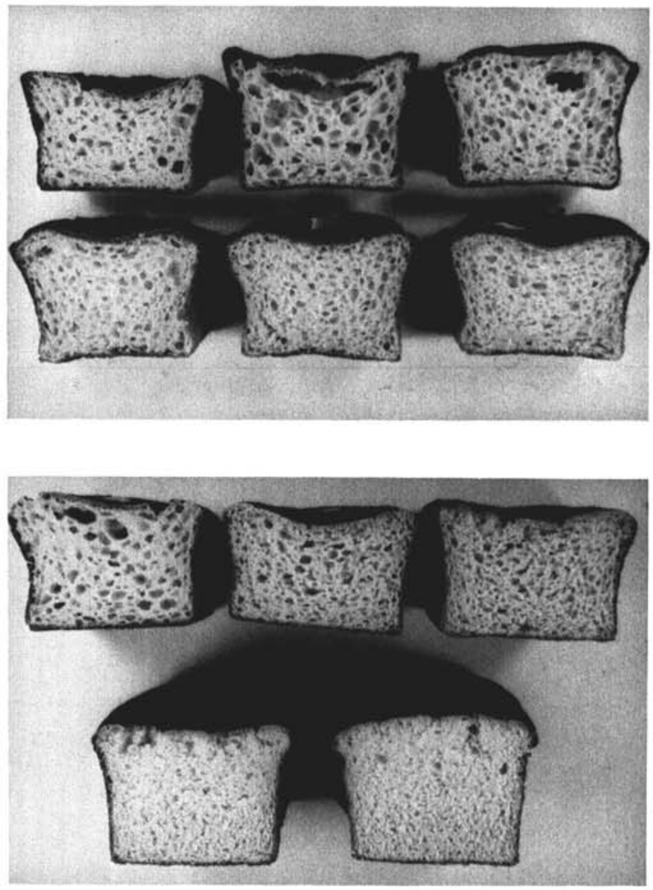

Fig. 1. Typical crumb structures of cassava breads produced with increasing amounts of extruded starch (top) and glyceryl monostearate (bottom) according to the procedure outlined in the text. For extruded starch, 0, 3, or 6% (top line, left to right) and 9, 12, or 15% (bottom line, left to right) were used. Breads with 0, 1, 2, 3, or 4% glyceryl monostearate are positioned in a similar manner.

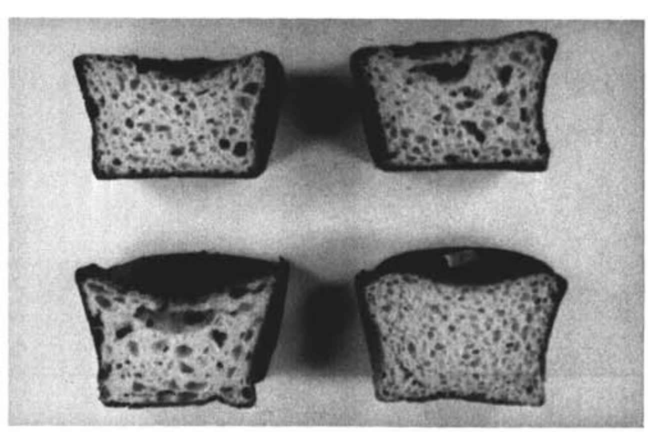

Fig. 2. Typical crumb structures of cassava breads produced from cassava flour (top line, left), cassava flour of which 12% was prehydrated (top line, right), cassava flour with 12% prehydrated corn starch (bottom line, left), and cassava flour with 12% prehydrated extruded corn starch (bottom line, right). The breads were produced according to the procedure outlined in the text.

GMS are at variance with those reported by Jongh (1961) for corn starch doughs with the addition of 1% GMS.

Pasting Properties of Batter and Bread Crumb

Figure 5 shows viscoamylograms of fermented batters in the presence and absence of 12% extruded starch or 4% GMS, and the viscoamylograms of the resulting bread crumbs are shown in Figure 6. The extruded material reduced the intensity of the peak of maximum viscosity (Fig. 5). This is easily explained by the fact that the added material contains a high percentage of soluble material. The effect of the surfactant as an agent delaying the maximum viscosity peak has been interpreted by other workers. In the cooking phase as well as in the cooling phase, GMS leads to greater viscosity, whereas extruded starch lowers the viscosity readings. The amylograms of the bread crumbs (Fig. 6) again reveal that in the presence of GMS the pasting behavior is different from that found when extruded starch is added to the formula. From all this data, it is tempting to speculate that the contribution by extruded starch or GMS to the bread baking potential of cassava bread is not due to their influence on the starch pasting characteristics. Visco-amylograms of unfermented

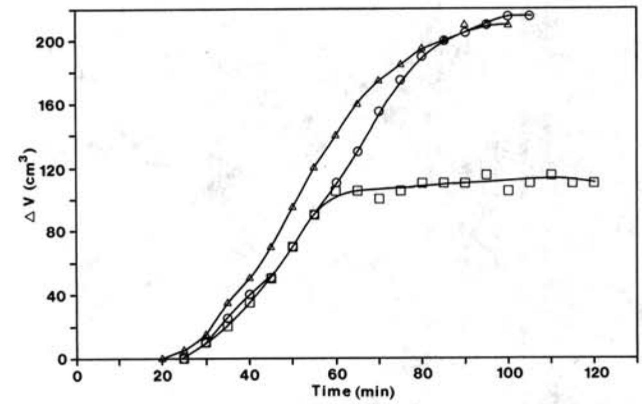

Fig. 3. Volume increase of cassava bread batters recorded at 5-min intervals for formulas without (□) and with 3% glyceryl monostearate (○) or 12% extruded corn starch (△). Batters contain 50% of the ingredients listed in Table I.

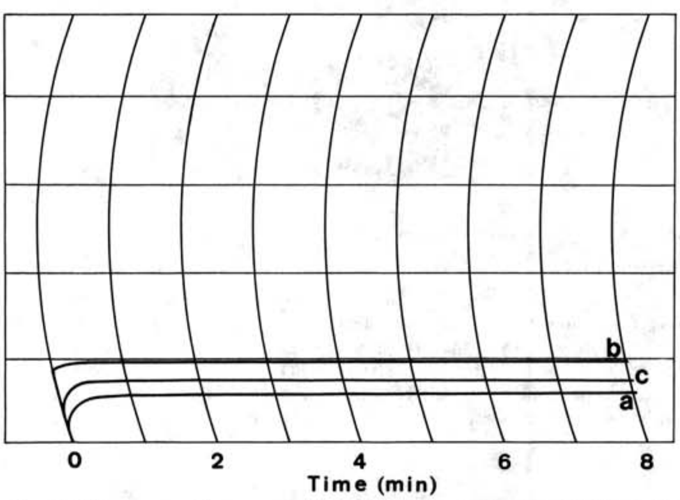

Fig. 4. Mixograms of cassava bread batters prepared without (a) or with 12% extruded corn starch (b) or 3% glyceryl monostearate (c).

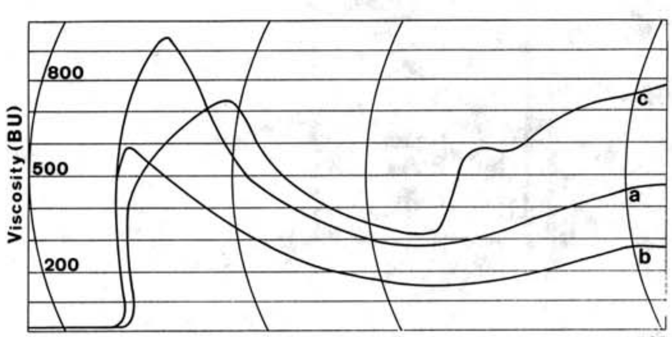

Fig. 5. Viscoamylograms of fermented cassava bread batters in the absence (a) or presence of 12% extruded starch (b) or 4% glyceryl monostearate (c).

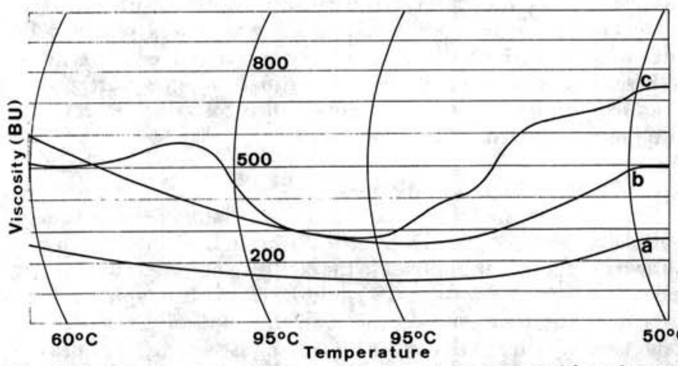

Fig. 6. Viscoamylograms of crumb of cassava breads prepared from batters without (a) or with 12% extruded starch (b) or 4% glyceryl monostearate (c).

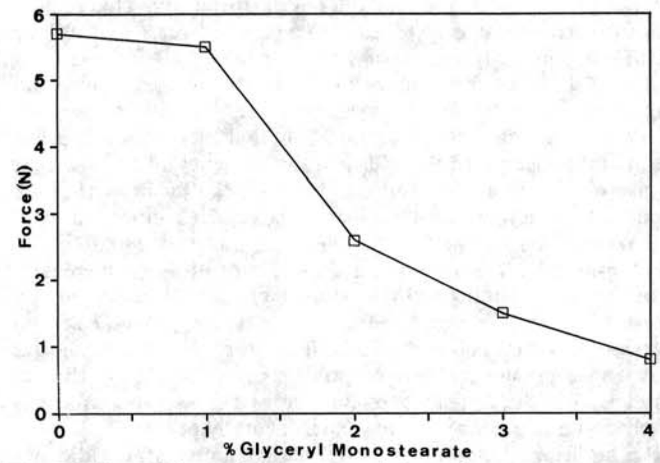

Fig. 7. Effect of increasing amounts of glyceryl monostearate cassava on bread firmness after 72 hr of storage.

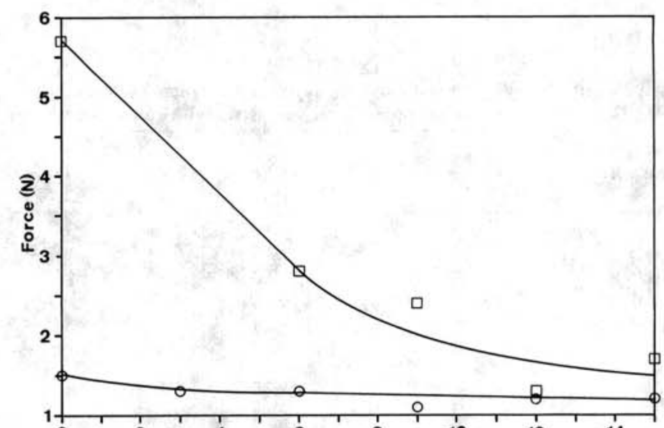

Fig. 8. Effect of increasing amounts of extruded corn starch in the presence (○) or absence (□) of 3% glyceryl monostearate on cassava bread firmness after 72 hr of storage.

yeasted dough were very comparable to those of the fermented dough and are therefore not shown.

Bread Firmness Evaluation

Bread firming as a function of the incorporation of the above agents in the bread formula was studied next.

A set of loaves with 3.0% GMS and varying concentrations (3.0–15.0%) of extruded starch was baked. The results of this work are shown in Figures 7 and 8. Small concentrations of GMS (2%) suffice to ensure much lower bread firmness after a 72-hr storage. A reduction in the firmness of the breads could equally be observed when extruded starch was used (Fig. 8), and the simultaneous use of GMS and extruded starch did not offer any additional advantages.

CONCLUSIONS

The production of wheatless breads from cassava is feasible if extruded starch or GMS is included in the formula.

The action of the former agent can be interpreted if one assumes that its primary effect is an increase in the viscosity of the fermenting batter, with an accompanying delay in the attainment of the (larger) critical buoyant size of the gas cells. Whether or not the decrease in the intensity of the amylograph pasting peak (under conditions of higher moisture than is the case in baking) can be related to the improving effect exerted by the pregelatinized material is not so clear.

The use of GMS results in better air uptake at the mixing stage, and this can be interpreted easily in terms of a reduction of the interfacial tension (Hoseney 1984a). More and smaller air bubbles are mixed in, and so gas is retained better during the fermentation phase because the gas cells take longer to attain the critical buoyant size.

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