Emulsifiers affect the texture of pastes made from fermented and non-fermented cassava flours†

Festus A. Numfor[2], William M. Walter Jr.*[1] & Steven J. Schwartz[3]

1 US Department of Agriculture, Agricultural Research Service, and North Carolina Agricultural Research Service, Department of Food Science, North Carolina State University, Raleigh, NC 27695-7624, USA
2 Present address: the Institute of Agricultural Research, Ekona Center, PMB 25, Buea, Cameroon
3 Present address: The Ohio State University, Columbus, OH, USA

Summary The effects of glycerol monostearate (GMS) and sodium steroyl lactylate (SSL) on the rheological properties of native, naturally fermented (NF) and mixed culture fermented (MCF) cassava flour pastes were measured using instrumental texture profile analysis (TPA) and by finger cohesiveness (difficulty in separation). Fermentation reduced the TPA parameters, hardness, cohesiveness and gumminess, but not springiness/elasticity. These were reduced further when either GMS or SSL were incorporated into the pastes. Pastes made from native and naturally fermented flours were scored by a Cameroonian sensory panel as difficult to separate, whereas scores for native and fermented flour pastes treated with 1% or more of GMS or SSL were easy to separate. Increased internal stability of the cassava flour starch granules was suggested as the cause of the effects.

Keywords Finger cohesiveness, fufu, glycerol monostearate, sodium steroyl lactylate, texture profile analysis.

Introduction

Emulsifiers are now established agents for improvement of texture in many starch-based foods such as pasta, bakery and mashed potato products (Krog, 1973). They aid control of texture because of retrogradation in bakery products, as well as stickiness in pasta and potato products.

In parts of West and Central Africa, cassava is commonly consumed as a paste ('fufu') usually made from the fermented flour and hot water (Numfor & Lyonga, 1987; Octavio & Harry, 1988; Hahn, 1989), although sometimes unfermented flour is used. The paste develops a high degree of cohesiveness (stickiness), which is disliked outside its traditional base and reduces the export potential of the cassava (Odigboh & Mohsenin, 1975; Osuji, 1983; Phan & Mercier, 1984). The cohesiveness also limits its use in other recipes as a local replacement for imported food (FAO, 1990).

Both fermentation and emulsifying agents can change the physicochemical properties of cassava starch and flour pastes (Numfor *et al.*, 1995; Numfor *et al.*, 1996). Fermentation improves internal stability of starch granules, with reduced swelling and decreased amylose solubility during heat treatment. The emulsifiers glycerol monostearate (GMS) and sodium steroyl lactylate (SSL) also increase granule stability by decreasing swelling and amylose leaching (Numfor *et al.*, 1996), probably by formation of an emulsifier–amylose complex and granule surface coating.

The objective of this study was to investigate the effects of GMS and SSL on the textural and sensory properties of pastes made from native and fermented cassava flours.

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*Correspondent: USDA-ARS, Box 7624, NC State University, Raleigh, NC 27695-7624, USA. Fax: +1 919-856-4361. e-mail: wmwalter@ncsu.edu

Materials and methods

Fresh cassava roots ('red-skin' variety) of unknown age and origin were purchased from a local supermarket. They were in excellent condition, with no signs of vascular streaking or other post-harvest deterioration. Enough roots were purchased from the same lot to prepare sufficient fermented and native flours to conduct the entire study. *Bacillus subtilis* ATTC 33712 and *Candida krusei* were from the American Type Culture Collection (Rockville, MD, USA), and *Lactobacillus plantarum* strain LA 102, No. 83, was from our laboratory. GMS and SSL were from Specialty Industrial Products (Spartanburg, SC, USA); all other chemicals were of laboratory grade.

Flour preparation

Native and fermented cassava flours were prepared as previously described (Numfor *et al.*, 1995). For unfermented cassava flour (native), fresh roots were peeled, washed, sliced (5 mm) and dried at 40 °C for 12 h and ground to pass a US No. 40 sieve to remove excess fibre. For traditional, naturally fermented cassava flour (NF), fresh roots were peeled, washed, cut into about 50-mm slices, immersed in tap water, covered with cheesecloth, and allowed to ferment naturally at 23–25 °C for 7 days until sample pulp crumbled between the fingers on slight pressing. After draining, the pulp was dried at 40 °C for 12 h, ground into a flour in a laboratory mill and excess fibre removed as above. For mixed culture fermented cassava flour (MCF), the procedure described by Oyewole (1990) was followed, except that, for safety considerations, sterilization with mercuric chloride was omitted. It was assumed that by adding 10^6 CFU mL^{-1}, the added cultures would outgrow the indigenous ones. A mixture containing *B. subtilis*, *L. plantarum*, and *C. krusei*, each at 10^6 CFU mL^{-1}, was used in an incubation chamber at 30 °C and 90% relative humidity. Roots became soft at the end of 4 days, and flour was prepared as described above.

Emulsifiers were each mixed with water (1:10 by weight) and allowed to swell at 70 °C for 30 min (GMS) or at 23–25 °C for 6 h (SSL) before being added to the flours at 0.5, 1.0 and 2.0% levels, based on flour dry weight (Eliasson, 1986).

Proximate composition of the flours was determined by standard methods of the AOAC (1984) for plant materials, cyanide content according to Cooke (1978), and amylose content by the iodine binding method of McCready & Hassid (1943).

Texture profile analysis (TPA)

An Instron Universal Testing Machine model 1122 (Instron Corporation, Canton, MA, USA) was used according to the method of Bourne (1978). Each of the 30% flour dispersions was with no emulsifier; 0.5%, 1.0% and 2.05 GMS; and 0.5%, 1.0% and 2.0% SSL. Samples were prepared in a 10-mL, clear plastic syringe with a heat-sealed tip and immersed in boiling water for 15 min. The piston was introduced into the syringe and pushed down until the paste assumed a volume of 10 mL. The syringes were held at 10 °C for 6 h. The tip end 10 mm of the syringe (and paste) was cut off with a sharp edge, the remainder of the paste pushed out with the piston and a 16-mm middle portion cut off. This piece was then twice compressed axially to 75% of its length and relaxed in the Instron at 500 mm per min, with a 5-kg force load cell and chart speed at 1000 mm per min. The force curves were analysed for the TPA parameters: hardness, cohesiveness, gumminess, adhesiveness and springiness (Bourne (1978). Three replicate samples were analysed in duplicate for each paste.

Finger evaluation

Cassava flour pastes with or without emulsifier as above were prepared by stirring 200 g of flour in 400 g of boiling water for 5 min and allowing them to cool for another 5 min before forming into 'balls' of 20–25 g for testing. At each of four sittings, two sample sets containing a total of 10 or 11 samples of one 'ball' were served to assessors in booths on partitioned plates with each sample coded with a randomly selected three-digit number. Thus, each panelist evaluated each of the 21 samples twice. The panel of nine native Cameroonians familiar with the product scored samples for the degree of difficulty of separating with the thumb and forefinger a bite-size piece from the 'ball' of 'fufu'. The five-category scale was from very difficult to separate (i.e. very cohesive) at 5 to not difficult to separate (i.e. slightly cohesive) at 1.

Results and discussion

The proximate composition and some physical properties of the flours used in this study are given in Numfor *et al.* (1995). Fermentation of the cassava roots resulted in lowering the pH of its flour from 6.9 to about 4.5, and, as expected, soluble sugars, ash and cyanide were significantly reduced. There was an increase in total acidity and an apparent increase in amylose content, possibly because of the formation of amylose-like fragments resulting from enzymic hydrolysis of amylopectin (Numfor *et al.*, 1996).

Fermentation produces some small changes in the TPA components: cohesiveness, gumminess, hardness and springiness (Numfor *et al.*, 1995) (Tables 1–4). Cohesiveness, a measure of stickiness, decreased slightly in MCF flour pastes. Phan & Mercier (1984), using a texturometer, found a similar cohesiveness of 0.84 for native cassava flour paste (43% total solids, 0.5–1.0-mm particle sizes). Cohesiveness of the flour pastes was slightly depressed by GMS and more by SSL (Table 1).

Fermentation by both methods depressed gumminess slightly (Table 2). Both emulsifiers further decreased gumminess for all flours more by SSL than by GMS. Hardness was similarly decreased, but to a lesser extent (Table 3).

Springiness/elasticity showed no effect of fermentation and only with higher levels of SSL (Table 4).

Hardness, cohesiveness and gumminess are measures of different aspects of intermolecular forces between the starch molecules and swollen

Table 1 Cohesiveness (ratio)[1] at 10 °C of 30% pastes of native and fermented cassava flours in the presence of GMS or SSL

Emulsifier[2]		**Type of cassava flour paste**		
Type	**Concentration (%)**	**Native**	**Fermented naturally**	**Fermented with culture**
None	0.0	0.79 (0.02)	0.75 (0.06)	0.68 (0.04)
Glycerol monostearate (GMS)	0.5	0.64 (0.05)	0.71 (0.04)	0.65 (0.02)
	1.0	0.66 (0.02)	0.70 (0.02)	0.64 (0.03)
	2.0	0.60 (0.08)	0.65 (0.01)	0.64 (0.02)
Sodium steroyl lactylate (SSL)	0.5	0.40 (0.07)	0.04 (0.04)	0.32 (0.04)
	1.0	0.22 (0.04)	0.31 (0.08)	0.10 (0.02)
	2.0	0.20 (0.01)	0.22 (0.05)	0.11 (0.04)

[1] Each value represents a mean and standard deviation of two sample determinations, each replicated three times.

[2] Per cent emulsifier is expressed on flour dry-weight basis.

Table 2 Gumminess (kgf)[1] at 10 °C of 30% pastes of native and fermented cassava flours in the presence of GMS or SSL

Emulsifier[2]		**Type of cassava flour paste**		
Type	**Concentration (%)**	**Native**	**Fermented naturally**	**Fermented with culture**
None	0.0	1.79 (0.04)	1.53 (0.14)	1.46 (0.12)
Glycerol monostearate (GMS)	0.5	1.17 (0.09)	1.24 (0.09)	1.26 (0.15)
	1.0	1.25 (0.13)	1.28 (0.03)	1.38 (0.08)
	2.0	1.07 (0.23)	1.19 (0.05)	1.12 (0.05)
Sodium steroyl lactylate (SSL)	0.5	0.76 (0.15)	0.78 (0.11)	0.62 (0.11)
	1.0	0.24 (0.04)	0.44 (0.11)	0.11 (0.01)
	2.0	0.11 (0.00)	0.36 (0.04)	0.10 (0.01)

[1] Each value represents a mean and standard deviation of two sample determinations, each replicated three times.

[2] Per cent emulsifier is expressed on flour dry-weight basis.

Table 3 Hardness (kgf)[1] at 10 °C of 30% pastes of native and fermented cassava flours in the presence of GMS or SSL

Emulsifier[2]		Type of cassava flour paste		
Type	Concentration (%)	Native	Fermented naturally	Fermented with culture
None	0.0	2.25 (0.02)	2.03 (0.03)	2.13 (0.05)
Glycerol monostearate (GMS)	0.5	1.82 (0.04)	1.76 (0.08)	1.94 (0.26)
	1.0	1.87 (0.16)	1.83 (0.08)	2.14 (0.05)
	2.0	1.78 (0.15)	1.72 (0.08)	1.74 (0.06)
Sodium steroyl lactylate (SSL)	0.5	1.91 (0.04)	1.97 (0.09)	1.94 (0.12)
	1.0	1.12 (0.09)	1.45 (0.03)	1.10 (0.18)
	2.0	0.65 (0.03)	0.70 (0.17)	0.75 (0.21)

[1] Each value represents a mean and standard deviation of two sample determinations, each replicated three times.

[2] Per cent emulsifier is expressed on flour dry-weight basis.

Table 4 Springiness/elasticity (mm)[1] at 10 °C of 30% pastes of native and fermented cassava flours in the presence of GMS or SSL

Emulsifier[2]		Type of cassava flour paste		
Type	Concentration (%)	Native	Fermented naturally	Fermented with culture
None	0.0	11.33 (1.04)	11.17 (0.76)	10.67 (0.58)
Glycerol monostearate (GMS)	0.5	9.17 (0.29)	10.33 (0.29)	9.83 (0.58)
	1.0	9.00 (0.50)	9.83 (0.58)	9.83 (0.29)
	2.0	8.83 (1.15)	10.33 (0.29)	9.50 (0.00)
Sodium steroyl lactylate (SSL)	0.5	7.17 (0.76)	6.33 (1.15)	5.67 (0.58)
	1.0	4.50 (0.87)	4.00 (0.50)	2.17 (0.29)
	2.0	3.00 (0.00)	4.33 (1.04)	2.17 (0.58)

[1] Each value represents a mean and standard deviation of two sample determinations, each replicated three times.

[2] Per cent emulsifier is expressed on flour dry-weight basis.

granules in the paste. The decrease in cohesiveness and gumminess of the fermented flour pastes is attributed to decreased volume fraction due to lower granule swelling power, and decreased amylose leaching, a result of increased granule internal stability (Numfor *et al.*, 1996). Miller *et al.* (1973), attributed viscosity development in a heated wheat starch–water suspension to both amylose leaching and intact granule sizes, and Wong & Lelievre (1982) attributed differences in dynamic rigidity and viscosity of pastes cooled to 30 °C to the volume fraction of the swollen starch granules.

Cohesiveness, gumminess and hardness were further depressed by GMS and SSL, and springiness by SSL. Kite *et al.* (1963) explained that surfactants limit both the gelatinization of starch and the hydrogen bonding of adjacent starch molecules by causing them to coil about the fatty acid tail. Ghiasi *et al.* (1982) showed that GMS and SSL inhibited both swelling and solubility below 85 °C by preventing amylose exudation. With reduced leaching of amylose and the presence of emulsifiers, the elastic quality of the paste is diminished because the starch molecules cannot establish enough junction zones of adequate size to give an elastic network.

The data on adhesiveness, a measure of the high forces between cassava paste and the contact surface, were inconsistent (data not shown), possibly because of fouling of the contact surfaces of the instrument.

Finger separation of flour paste balls (Table 5) showed that those made from native and naturally fermented flours without emulsifier were given scores in the difficult to very difficult to separate range (> 4.0), indicating that these pastes were cohesive or sticky, whereas those for pastes with

Table 5 Mean scores[1,2] for finger separation difficulty of 30% cassava flour pastes with or without added emulsifier

Emulsifier[2]		Type of cassava flour paste		
Type	**Concentration (%)**	**Native**	**Fermented naturally**	**Fermented with culture**
None	0.0	4.1 (0.4)	4.0 (0.3)	3.3 (0.2)
Glycerol monostearate (GMS)	0.5	3.0 (0.2)	2.3 (0.1)	3.0 (0.1)
	1.0	2.4 (0.2)	2.0 (0.1)	2.8 (0.2)
	2.0	2.4 (0.1)	2.2 (0.2)	2.2 (0.1)
Sodium steroyl lactylate (SSL)	0.5	2.3 (0.2)	2.3 (0.1)	2.3 (0.2)
	1.0	1.2 (0.0)	1.4 (0.1)	1.2 (0.0)
	2.0	1.0 (0.0)	1.2 (0.1)	1.2 (0.1)

[1]Panelists were asked to separate a bite size piece of cooked paste with their fingers and rate each on a five-point scale how easy or difficult it was. Each value is an average of two separate evaluations: 5 = very difficult, 4 = difficult, 3 = neither difficult nor easy, 2 = easy, 1 = very easy.

[2]Standard deviation.

higher levels of GMS and all levels of SSL were in the easy to very easy to separate range, indicating a lack of cohesiveness or stickiness (< 2.5).

Pearson correlation coefficients (SAS, 1984; Steel & Torrie, 1980) showed statistically significant relationships (r = > 0.93) between average granule diameter, TPA cohesiveness and TPA gumminess on the one hand, and finger cohesiveness on the other. This suggests that it is the swelling of the granule that leads to the development of those parameters, which are slightly different aspects of the same complex of rheological properties and of the human sensory experience.

Conclusions

Balls of pastes made from cassava flour, whether fermented or not, when treated with GMS, or more effectively SSL, were much less cohesive (less difficult to separate with fingers) than untreated pastes. This was closely related to instrumental measures of 'fufu' cohesiveness and gumminess made from either native or fermented cassava flour pastes.

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