Formulation of an Infant Food Based on Breadfruit *(Artocarpus altilis)* and Breadnut *(Artocarpus camansi)*

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Abstract

The availability of nutritious and palatable high-protein infant foods made from local staple crops is essential to proper health and nutrition of children. New product development studies were carried out to formulate an infant food from breadfruit (*Artocarpus altilis)* pulp and breadnut (*Artocarpus camansi)* seeds, which are locally available in Ghana, in combination with roasted malted maize and roasted groundnuts. Granulated sugar, full-fat powdered milk and dried powdered carrots were also incorporated into the formula. Physicochemical studies (proximate and functional analyses) on the raw ingredients and the formulated products included moisture, ash, protein, fat, fibre and carbohydrate contents and also water-binding capacity, solubility, swelling power, viscosity and dispersability. Analyses on a local infant food and a commercial infant food, both maize-based, were made for comparison purposes. Roasting of the ingredients reduced their moisture content, increasing shelf life and providing an advantage in product development. Malting the maize reduced its water-binding capacity and viscosity while increasing solubility. Sensory evaluation of the formulated products revealed that the formulation with 50% *Artocarpus altilis* pulp, 40% malted, roasted maize and 10% roasted groundnuts had the most preferred attributes in terms of aroma, texture, mouthfeel, sweetness, aftertaste and overall acceptability. Proximate analysis of this product showed: 7.9% moisture, 2.2% crude ash, 1.9% crude fibre, 14.7% crude protein, 9.9% crude fat and 63.5% carbohydrate, indicating that this infant food was comparable to the commercial infant food with respect to protein and fat. The incorporation of breadfruit and breadnut into locally-produced infant foods can provide a nutritious and palatable alternative. It is therefore expedient to formulate infant foods from local staples that are nutritious, fit into the traditional culinary and child-feeding practices of the region and are affordable.

INTRODUCTION

Infant nutrition in the first two years of life has long-term consequences on the health and productivity of that individual. Infants in developing countries generally show satisfactory growth during the first six months of life when they are almost exclusively breastfed (Jansen, 1992). Inappropriate complementary food to breastmilk has been identified as a contributing factor to the high incidence of malnutrition in developing countries (WHO/UNICEF, 1998). Among the many approaches needed to improve child survival and growth in developing countries is the provision of safe and nutritious infant foods (Jansen, 1992). Traditional infant porridges in developing countries are usually made from local staples and the resulting gruels may have low nutritional value in terms of micronutrients and macronutrients (Brown, 1991). In Ghana, for example, a traditional infant food prepared from roasted, milled maize and commonly known as "tom brown" is fed to infants as a complement to breastmilk from as early as 5-6 months. The nutrient content of this product, however, is far below the recommended values for infant foods and cannot meet the nutritional demands of an infant. Although a number of commercial infant foods exist, most families in the low- and middle-income earning groups cannot afford them. It is therefore expedient to formulate infant foods from local staples that are nutritious, fit into the traditional culinary and child-feeding practices of the region and are affordable. In developing countries like Ghana, some development of high-protein infant foods has been done by fortifying cereals with legumes (soy beans and cowpeas) (Akpapunam and Sefa-Dedeh, 1995).

More studies are needed to reduce the viscosity and dietary bulk of traditional infant food products. An infant food requirement now emphasized is a high caloric density per unit volume of food which can be obtained by reducing the viscosity of the product. Breadfruit and breadnut are neglected but highly nutritious crops containing macronutrients (e.g., protein) and micronutrients (e.g., minerals) suitable for infant food formulations. Thus, in order to reduce the incidence of protein-energy malnutrition in Ghana, and perhaps other parts of the West African subregion, breadfruit and breadnut were selected for use in developing a local infant food formula, using traditional technologies to reduce product viscosity to provide desirable functional and nutritional qualities.

MATERIALS AND METHODS

The locally available crops used to formulate the infant food were breadfruit pulp, *Artocarpus altilis* (Parkinson) Fosberg, breadnut seeds (*Artocarpus camansi* Blanco), maize, groundnuts (*Arachis hypogaea* L.) and carrots.

Processing of Raw Materials

Mature, firm fruits of breadfruit were hand-picked and sorted. They were washed and peeled in water to avoid browning. The cores were removed and the remaining pulp cut into thin slices about 2 mm thick. The sliced pulp pieces were pre-gelatinised by immersing the pulp chips in hot water, then were drained and solar-dried at a temperature of 55°C for 4 d. Dried chips were milled using a hammer mill and the resulting flour sieved. Ripe breadnut fruits were gathered after they had dropped from the tree and sorted and washed. Seeds were extracted from the pulp by hand, crushed and dried in a solar dryer at 55°C for 4 d, dehulled and roasted in a gas oven at 120°C for 20 m then milled using a hammer mill and the resulting flour sieved.

Maize was sorted, washed and steeped for 48 h. After this treatment, the grains were spread on a moistened jute sack for 2 d and allowed to germinate. After sprouting, the grains were solar-dried at 55°C for 3 d and the vegetative portion was removed by gentle abrasion. Dried maize grains were roasted at 140°C for 30 m in a gas oven until golden brown. Milling was done using a hammer mill and the resulting sieved. Groundnuts were sorted and roasted at 130°C for 25 m in a gas oven, then dehulled and milled. Firm, ripe carrots were washed and processed into thin chips using a locally assembled mechanical chipper, then solar-dried at 55°C for 2 d and milled.

Formulation of Blends

Six different blends were formulated using varying percentages of the ingredients (Table 1). For the purpose of viscosity analysis and comparison, two additional blends were formulated. To each blend, the following additives were incorporated: 10% full-fat milk powder, 10% granulated sugar and 5% powdered carrots. Each product (P) was assigned a unique identifying number.

Analytical Procedures

Physicochemical studies (proximate and functional analyses) were carried out separately on the various ingredients, formulated blends, a local infant formula made from roasted maize, and a commercial maize-based infant product. Proximate analysis was carried out using standard AOAC (1990) procedures and functional analysis was conducted using modifications of the methodology of Medcalf and Gilles (1965).

Sensory Evaluation

Sensory evaluation on the six formulated blends of infant food was conducted to assess scores for selected attributes including colour, aroma, texture, mouthfeel, sweetness, aftertaste and overall acceptability. A 25-member sensory panel was used for the evaluation. Mothers with infants starting complementary foods, and having no previous experience systematically evaluating infant foods, were trained to use a 7-point Hedonic scale ranging from “1=dislike very much” to “7=like very much.”

Statistical Analysis

Parametric and non-parametric data was generated from the laboratory analyses and the sensory evaluation test, respectively. Non-parametric data were subjected to frequency analysis using SPSS 11.0 while the average of the replicates of the data generated from laboratory work was computed and the results presented graphically using Microsoft Excel.

RESULTS AND DISCUSSION

Moisture, Ash and Fibre Contents

The moisture content of the formulated products ranged from 5.1-8.4% for P157 and P399, respectively (Table 2). The three products incorporating breadfruit had comparatively higher moisture content (7.9-8.4%) than the three products made with breadnut (5.1-5.3%). This trend could be attributed to the pretreatments the various ingredients received prior to the product formulation Moisture content of the breadfruit pulp products was higher due to pregelatinisation. However, breadnut seeds were solar-dried and roasted, thereby reducing the moisture content of the seed-formulated products. Moisture content is an indication product shelf life, a very important measure of product quality: the lower the moisture content, the longer the expected shelf life. Roasting breadnut seeds reduced the moisture content considerably from 6.4% to 1.7%, indicating the suitability of the roasted seeds for developing products with a longer shelf life. The local product had a very low moisture content of 2.3% because the raw ingredient used (maize) was roasted.

The ash content of all six breadfruit- and breadnut-formulated products was higher than the local infant food. Since crude ash is a reflection of the mineral content, the reduction in ash content of maize after malting (from 1.6% to 1.2%) and of breadfruit pulp flour after pregelatinising (from 3.2% to 2.8%) could be due to minerals leaching during the malting and pregelatinisation processes (Obatolu et al., 2000). Ash contents of both breadfruit and breadnut were relatively higher than in maize (Table 3) indicating they could serve as better mineral sources for developing an infant food compared to the widely known and accepted maize. However, this is not the only criteria for selecting a material for infant food production.

All the products had fibre contents within the proposed range of less than 5% for infant foods (Codex Alimentarius, 2000). Of all the ingredients used in the formulation, the fibre content of groundnut was highest (Table 3), thus, the four products containing groundnuts (P815, P269, P157 and P431) had slightly higher fibre content (1.9-2%) than P412 and P399 without groundnuts (1.3-1.5%) (Table 2).

Protein and Fat Content

About 15% protein content is desirable in infant food (Codex Alimentarius, 2000). Crude protein content ranged between 13.9-16% for the formulated products. The local product had the lowest protein content of 9.6% (Table 2). With the simple technology involved in formulating the breadfruit- and breadnut-based infant food, it is more likely to protect against protein-energy malnutrition in infants compared to the local product. Malting the maize increased its protein content from 13.4% to 15.6%, because germination converts insoluble proteins to soluble components and increases the overall level of proteins (Parameswaan and Sadasivam, 1994). This indicates the high suitability of malted maize for a weaning food formulation compared to dried maize. In addition, malting of cereals, as reported by Johnson et al. (2001) permits better digestibility of starch.

Crude fat content of the products ranged from 4.3% for the local product to 12% for P431 (Table 2). Fats contribute to energy density, one of the primary requirements in the formulation or improvement of infant foods (Brown, 1991). All formulations containing groundnuts had high fat content (9.9-12%), indicating at least 10% legumes (e.g., groundnuts or soybean) should be included in infant food formulations to improve fat content and energy density. The 4.3% fat content of the local product is far below the recommended value of 10% and cannot meet the nutritional demands of a growing infant.

Carbohydrate Content

Carbohydrate content reflects a food's caloric value and, hence, its energy density. An infant food is therefore expected to have appreciably high carbohydrate content. All the formulated products and the commercial product had a carbohydrate content greater than 60%, ranging from 62% for P431 to 67.9% for P399 (Table 2). The local product had a carbohydrate content of 81%, reflecting its low values for protein and fat.

Water-Binding Capacity

Water-binding capacities of the products ranged from 154.2% for the local product to 206.3% for P431 (Table 4). A high water-binding capacity increases a product's viscosity (consistency) when mixed with water, resulting in a thicker paste and increased bulk, thus limiting caloric intake when such meals are served to young children (Desikachar, 1980). Malting the maize reduced its water-binding capacity drastically from 246.4% to 113.5%, a reduction of about 50%. Svanberg (1987) and Mosha and Lorri (1987) reported that germination improves the nutritional value of infant foods by reducing the water-binding capacity of cereal flour which allows the porridge to have a free-flowing consistency, even with a high proportion of flour. In infant product development it is necessary to employ processing treatments, like malting, which lower the water-binding capacity and viscosity of the gruel, enhancing the caloric intake when fed to infants. Out of all six formulated products, P815 had the lowest water-binding capacity of 176%; it would be advantageous to use it for developing infant foods.

Swelling Power and Solubility

Swelling power of the products was between 7.2-11.7%. Generally the breadfruit products had higher swelling power values (9.3-11.7%) than the breadnut products (7.2-7.3%) (Table 4), reflecting the higher swelling power of pregelatinised breadfruit pulp (12.5%) compared to roasted breadnut seeds (9.4%) (Table 5). Due to breadnut's higher fat content, compared to breadfruit (Table 3), products from the seeds had a lower swelling power than the products from the pulp. Swinkels (1985) showed that the formation of lipid-starch complexes can inhibit swelling power of starches. Malting maize reduced swelling power from 11.7% to 7.7%. This might indicate that the amylose in the maize starch, which would otherwise have caused the starch to swell, was degraded into simple sugars by the activities of α-amylase and β-amylase which develop during germination of grains (Johnson et al., 2001).

The solubility of breadfruit-formulated products ranged from 29.4% (P815) to 33.4% (P399) (Table 4). A product with higher solubility would permit better digestibility when fed to infants, thus providing an advantage compared to one with a lower solubility. Malting maize increased its solubility significantly from 21.9% to 37.8% (Table 5) which might be due to the breakdown of the complex, insoluble maize starch into simpler, more soluble sugars which occurs during malting. According to Johnson et al. (2001), malted infant food can be expected to permit better starch digestibility as partial starch breakdown to dextrins occurs during malting. Lowered starch complexity and partial pre-digestion by enzymes during malting should help in its utilization by a child being weaned from a lactose-based milk diet to a starch-based cereal diet.

Dispersability

Product cold and hot water dispersabilities, estimated subjectively with scores of 1=poor, 2=fairly good, 3=good and 4=excellent, ranged between 1-4 (Table 4). In cold water, all three breadfruit products had fairly good dispersability while all three breadnut products had poor dispersability. In hot water, dispersability of all breadfruit-based products improved, with P412 and P399 having excellent dispersabilities. The commercial product had the best dispersability in cold water.

Viscosity

Desikachar (1980) stated that maximum reduction in paste viscosity is achieved through the process of malting, which in certain cases was found to effect a 10-fold reduction. Viscosity readings taken at room temperature using Spindle Number 3 of the Brookfield Viscometer ranged between 1400-28350 cP (Fig. 1). P119 (50% breadfruit pulp, 40% dried unmalted maize and 10% groundnuts) registered the highest viscosity of 28350 cP while its equivalent, P815 (formulated with the same proportion and composition of ingredients except that 40% malted maize was used instead of dried unmalted maize) had its viscosity reduced drastically to 2400 cP, a reduction of about 12-fold. In the same manner, P137 (50% breadnut, 40% dried unmalted maize and 10% groundnuts) had a viscosity of 11700 cP while its equivalent, P269 (50% breadnut, 40% malted maize and 10% groundnuts), had its viscosity reduced to 1400 cP, a reduction of about 8-fold (Fig. 1).

EVALUATION OF SENSORY ATTRIBUTES OF FORMULATED INFANT PRODUCTS

Colour and Aroma

For colour (Fig. 2), P815 (mean 5.3) was the most preferred while the product with the least preferred colour was P399 (mean 4.0). P815 was also the most preferred for aroma (5.4), followed by P412 with a mean score of 4.8 The aroma of P815 was the most preferred, probably due to the relatively high percentage of roasted maize and roasted groundnuts with which sensory panelists might already be familiar. The relatively high fat content of this product also could account for this observation since fat is known to improve the general palatability of food products (Fennema and Tannenbaum, 1976).

Texture and Mouthfeel

For both texture and mouthfeel (Fig. 2), P815, again, was the most preferred with mean scores of 5.3 and 4.9, respectively. P412 was the second most preferred in terms of texture with a mean score of 4.9. P269 and P157 with 30% or 40% roasted maize, were more preferred in terms of texture and mouthfeel than P431 (20%). Another interesting observation was that the mean scores for the mouthfeel of P269, P157 and P431 decreased as the content of roasted maize progressively decreased from 40% to 20%. These products had mean scores of 4.7, 4.4 and 4.0, respectively. These two observations further buttress the earlier assertion that the choices of sensory panelists were influenced by their familiarity with roasted maize and groundnuts in infant foods.

Sweetness and Aftertaste

For both sweetness and aftertaste (Fig. 2), P815 again topped the list with mean scores of 5.2 and 4.9, respectively. P815 probably had a significantly higher mean score for sweetness because panelists' choices may have been influenced by its other preferred attributes of aroma, texture, mouthfeel, aftertaste and overall acceptability. P431 had the least preferred aftertaste (3.2), probably due to its relatively low content of maize and groundnuts. As with mouthfeel, it was observed that products with decreasing levels of roasted maize had decreasing mean scores for aftertaste.

Overall Acceptability

P815 had the highest acceptability score (6.7), followed by P412 at 6.0. P399, P269 and P157, with a maize content of 20-40%, performed fairly well with mean scores of 5.5-5.6 (Fig. 2),

CONCLUSION

In formulating an infant food product, malting of the cereal should be an integral part of the process. Although malting slightly reduces the ash content, it has the benefit of reducing water-binding capacity, increasing solubility and therefore permitting better digestibility when fed to infants and, above all, reducing viscosity. Of all the formulated products, P815 (composed of 50% breadfruit pulp, 40% malted, roasted maize and 10% groundnuts) had the most preferred attributes of low water-binding capacity, aroma, texture, mouthfeel, sweetness, aftertaste and overall acceptability and, thus, would be advantageous to use for an infant food. The breadfruit- and breadnut-formulated infant food products had desirable physicochemical properties with reference to the proposed model for complementary foods provided by the Codex Alimentarius Commission Standards.

In comparing the breadfruit- and breadnut-based infant products to roasted and milled maize, a traditional infant food used mainly by the low- and middle-income earning group in Ghana, it can be concluded that breadfruit and breadnut products are more nutritious because they had higher ash, protein and fat content than the traditional infant food whose nutrient content is far below the recommended value and cannot meet the nutritional demands of an infant. Thus, with the simple technology involved in formulating a breadfruit/breadnut-based infant food, it is more likely to protect against protein-energy malnutrition in infants compared to "tom brown."

The infant foods developed for this study were comparable to the commercial infant food with respect to protein and fat content, both critical attributes in formulating infant foods. However, commercially processed weaning formulas are quite expensive and may be available only to children of higher income earning families. Breadfruit is both highly nutritious and a locally available crop which can be used for infant foods in combination with other locally available crops. Planting and cultivating breadfruit and breadnut does not involve cumbersome procedures and these crops have the potential of large-scale cultivation. They are aptly suited to the tropical climate and soil conditions of Ghana. Nutritious and tasty infant food with desirable nutritional and sensory characteristics can be locally produced by using breadfruit and incorporating other local ingredients like maize and groundnuts.

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Tables

Table 1. Composition of six infant food formulations containing various percentages of breadfruit, breadnut, roasted maize and groundnuts.

Product	Breadfruit[1]	Breadnut[2]	Maize[3]	Groundnuts[4]
412	50	10	40	
399	60	10	30	
815	50		40	10
269		50	40	10
157		60	30	10
431		70	20	10

[1] Pregelatinised breadfruit pulp; [2] Roasted breadnut seeds; [3] Malted, roasted maize;
[4] Roasted groundnuts.

Table 2. Proximate analysis of breadfruit/breadnut-formulated infant foods containing maize, and groundnuts, and a local and commercial infant food.

Product	Moisture	Ash	Fibre	Protein	Fat	Carbohydrate
412	8.1	2.3	1.3	13.9	6.6	67.8
399	8.4	2.3	1.5	13.9	6.1	67.9
815	7.9	2.2	1.9	14.7	9.9	63.5
269	5.3	2.4	2.0	15.4	10.8	64.1
157	5.1	2.8	2.0	15.6	11.3	63.3
431	5.2	2.9	2.0	16.0	12.0	61.9
Local	2.3	1.4	2.4	8.6	4.3	81.0
Commercial	5.3	3.3	4.8	15.5	9.0	62.1

Table 3. Proximate analysis of breadfruit pulp, breadnut seeds, maize and groundnuts used in the formulation of infant foods.

Ingredient	Moisture	Ash	Fibre	Protein	Fat	Carbohydrate
Raw pulp	5.5	3.2	1.2	6.2	2.3	81.7
Pregel pulp	7.0	2.8	0.9	6.0	2.0	81.3
Dried seeds	6.4	3.1	1.3	18.4	7.7	63.1
Roasted seeds	1.7	3.2	1.9	14.3	6.7	72.2
Dried maize	2.1	1.6	1.6	13.4	8.0	73.4
Malted maize	8.0	1.2	0.9	15.6	5.0	69.3
Roasted maize	4.6	1.3	0.9	14.3	4.9	74.0
Roasted groundnuts	7.8	3.8	2.0	25.0	45.0	16.4

Table 4. Functional properties of breadfruit/breadnut-formulated infant products, a local infant food and a commercial infant food.

Product	Water Binding Capacity	Swelling Power	Solubility	Dispersability	
				Cold Water	Hot Water
412	191.7	11.7	30.1	2	4
399	204.4	11.1	33.4	2	4
815	176.0	9.3	29.4	2	3
269	183.0	7.2	32.7	1	3
157	197.8	7.2	30.9	1	3
431	206.3	7.3	30.3	1	3
Local	154.2	8.6	21.8	2	4
Commercial	182.4	10.1	25.9	3	4

Table 5. Functional characteristics of breadfruit pulp, breadnut seeds, maize and groundnuts used in the formulation of infant food.

Ingredient	Water Binding Capacity	Swelling Power	Solubility	Dispersability	
				Cold Water	Hot Water
Raw pulp	219.0	9.9	10.3	3	4
Pregel pulp	231.5	12.5	13.8	4	4
Dried seeds	216.2	8.7	17.0	2	3
Roasted seeds	282.1	9.4	18.5	1	3
Dried Maize	246.4	11.7	21.9	3	4
Malted maize	113.5	7.7	37.8	1	2
Roasted maize	151.4	8.2	15.0	1	2

[1]Dispersability: 1=poor; 2=fairly good; 3=good and 4=excellent.

Figures

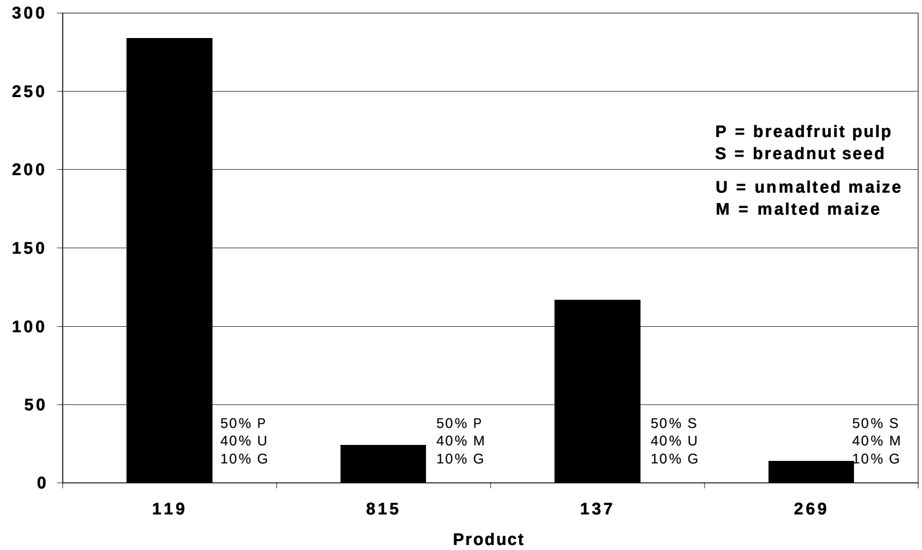

Fig. 1. Comparison of viscosity for four infant food products containing breadfruit (50%), breadnut (50%), groundnuts (10%) and unmalted (40%) or malted maize (40%).

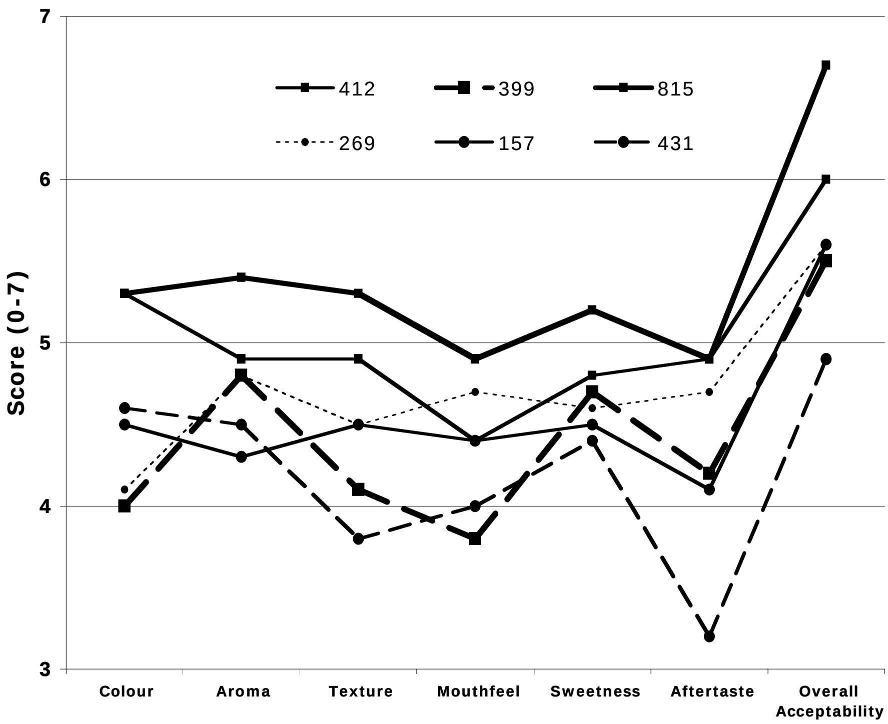

Fig. 2. Sensory evaluation scores of formulated products. Scores based on a 7-point Hedonic scale ranging from 1 = "dislike very much" to 7 = "like very much."