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Nutritional Properties of Enriched Local Complementary Flours

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Abstract: This study aimed to identify the nutritional, functional, sensory and microbiological profile of experimental nutritional flours, produced with local products in Burkina Faso. The raw materials included maize (*Zea mays*), millet (*Pennisetum glaucum*) and rice (*Oryza sativa*). Local ingredients were pulps of *Adansonia digitata* and *Parkia biglobosa* and seeds of *Cucurbita maxima* and *Moringa oleifera*. Three formula were developed, the first (F1) with maize, the second (F2) with rice and the last (F3) with millet. Each of these cereals was mixed with predetermined portions of seeds and pulps in order to obtain enriched flour. Nutritional, microbiological and functional analysis and the acceptability criteria of these enriched flours were assessed and compared to Misola (F4), the existing local complementary flour. The fat content of experimental flours were respectively in the first (F1), second (F2) and third formula (F3) 15.91±0.01%, 11.82±0.02% and 17.02±0.02%. The carbohydrate range was 65.46±0.06%, 70.81±0.01% and 64.51±0.01% for F1, F2 and F3, while the energetic value is higher than recommended (453.07±0.05, 424.56±0.03 and 458.96±0.05 kcal respectively for F1, F2 and F3). Functional characteristics indicated the good viscosity (117, 119 and 121 mm/30 sec for F1, F2 and F3) least gelation (9, 6 and 7%) and water absorption capacity (2, 4 and 1 g/g). Trained sensory evaluation panellists gore the enriched flour porridge a score of acceptable. These enriched flours have great potential as a weaning food in resource-poor and technologically under-developed countries.

Key words: Flour formulation, local ingredients, malnutrition

INTRODUCTION

Malnutrition constitutes a serious problem for children between 6 to 18 months of age, the period of complementary feeding (Waterlow, 1988; WHO, 1998). In order to reduce high morbidity and mortality due to malnutrition, attention has been focused on the exploitation and utilization of plant resources (Hassan and Umar, 2005), which are largely unexploited (Oliveira *et al*., 2000; Parvathin and Kumar, 2002). Many plant proteins, usually in the form of protein extracts or seed flours, were investigated and tested for new products such as low-cost formulated foods which are nutritious, food-based approaches, attractive and acceptable to children and mothers (Lin *et al.*, 1974; McWatters and Cherry, 1977). A number of cereals and legumes that are readily available in Ouagadougou, Burkina Faso, have been found to have nutrient potentials that could complement one another if properly processed and blended (Oguntona *et al*., 1995; Fernandez *et al*., 2002). The high cost of fortified nutritious proprietary complementary foods is always beyond the reach of most Burkinabe households (Traoré, 2005; Bruyeron *et al*., 2010). Such households often depend on inadequately processed traditional foods consisting mainly of un-supplemented cereal porridges made from maize, sorghum and millet (Tou, 2007).

The objective of this study was to determine physico chemical, functional, microbiological and sensorial characteristics of three enriched flours produced with locally available raw materials. Then, these characteristics were compared to Misola, the existing complementary flour produced by Centre Médical Saint Camille of Ouagadougou for children recovering from malnutrition (Laurent, 1995).

METHODOLOGY

Site of study: This study was conducted from February to September 2010 at the Biological, Food and Nutritional Research Centre (CRSBAN), at the University of Ouagadougou (Burkina Faso) for flour formulation,

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analysis and degustation, and at Centre Médical Saint Camille of Ouagadougou for degustation test with malnourished children's mothers.

Material: The foodstuffs and seeds of *Curcurbita maxima* were purchased from local markets while seeds of *Moringa oleifera* were harvested in the National Park of Ouagadougou, Burkina Faso. For comparison purposes, Misola was purchased from Centre Medical Saint Camille of Ouagadougou.

Treatment of raw materials: The dehulled cereals - paddy rice, yellow maize and no peel pearled millet - were separately washed several times with tap water, air-dried for 12 h, and roasted at 90ºC for 30 min. The *Cucurbita maxima* seeds were cleaned manually to remove foreign matter and immature and damaged seeds, then washed and air dried for 5 h and roasted at 70ºC for 15 min. Seeds of *Moringa oleifera* were dehulled and roasted at 70ºC for 15 min to reduce the bitter flavour before using.

Formulation of composite flours: Three complementary flours (F1, F2 and F3) were formulated as follows:

Flour 1 (F1): *Zea mays*: *Cucurbita maxima*: *Moringa oleifera*: Pulps of *Parkia biglobosa*: pulps of *Adansonia digitata*: sugar: (60: 20: 10: 4: 2: 4 % w/w).
Flour 2 (F2): *Oriza sativa L.*: *Cucurbita maxima*: *Moringa oleifera*: Pulps of *Parkia biglobosa*: pulps of *Adansonia digitata*: sugar: (60: 21: 12: 2: 3: 2 % w/w).
Flour 3 (F3): *Pennisetum glaucum*: *Cucurbita maxima*: *Moringa oleifera*: Pulps of *Parkia biglobosa*: pulps of *Adansonia digitata*: sugar: (60: 22: 10: 4: 2: 2 % w/w).
Flour 4 (F4): Misola (developed by Centre Médical Saint Camille of Ouagadougou): *Pennisetum glaucum*: *Soja hispida*: *Arachis hypogae*: sugar: (60:20:10:10% w/w).

Cucurbita maxima belongs to *Cucurbitaceae* family and seeds contain 42% protein, 13.4% carbohydrates, 42.9-57.3% lipids and 4.33-7.25% ash (Phillips *et al*., 2005). *Moringa oleifera*, a member of the *Moringaceae* family, has been reported to contain 29.63-31.36% protein, 30.36-40.39% fat, 9% carbohydrate and 6-8% ash (Anwar *et al*., 2006). For each formula, all ingredients are weighted and mixed with an automatic mixer for 10 min and then crushed. One thousand grams of fresh flours were taken for nutritional, functional and microbiological analysis.

Physico chemical analysis: Nutritional composition of the experimental flours, including moisture, crude fat, crude protein and total ash, were determined using AOAC official methods of 925.09, 4.5.01, 979.09 and 923.03, respectively (AOAC, 2000). Titrimetric method was used to determine total carbohydrates according to the AOAC 939.03 (2005) official method. Results were expressed as g/100 g of dry matter. Energy value was calculated using Atwater's conversion factors, where carbohydrates and proteins give 4 kcal/g while lipids give 9 kcal/g (Spackman *et al*., 1958). Bags of 500 g were delivered in double plastic hygienic packaging with no apparent brand mark. Nutritional facts and instructions for safe handling and preparation were provided on the packaging.

Minerals analysis: For each formula, potassium and sodium content were assessed by flame spectrophotometer (Sena *et al*., 1998) while calcium, magnesium, manganese, iron, zinc and copper were analyzed using an atomic absorption spectrophotometer (Sena *et al*., 1998). Phosphorus was analyzed using Technicon Auto-analyzer methodology (Lockett *et al*., 2000).

Functional analysis:

Viscocity: For this study, 180 g of F1, F2 and F3 and 1000 mL of clean water were mixed and heated at 100ºC for 10 min. After cooking the porridge, temperature was followed until freezing around 45ºC and the measurement by Bostwick consistometer was done in triplicate with three different preparations (Mouquet *et al*., 2006).

Water absorption capacity: Water absorption capacity was determined by a modification of the method of Lin *et al*. (1974). One gram of each flour sample was weighed in a centrifuge tube and 10 mL of distilled water was added. Samples were vortexed for 5 min and allowed to stand for 15 min at room temperature (28±2ºC) before centrifuging at 3500 rpm for 30 min. Excess water was decanted; the sample was allowed to drain by inverting the tube over absorbent paper. The weight of water-bound samples was determined by difference.

Water solubility index: Water solubility index was determined by the method of Onwulata *et al*. (1998). Two grams of each sample flour was weighed into a porcelain dish and hydrated with 10 mL of distilled water. The hydrated flour was heated in a water bath at 100˚C for 30 min and allowed to cool to room temperature. The supernatant was decanted, weighed evaporated to dryness and weighed. Water solubility index was calculated as the weight percent of the dry supernatant.

Reconstitution time (s): Reconstitution time (in seconds) was determined by the method described by Nwanekezi *et al*. (2001). Two grams of each sample flour was spread on the surface of 50 mL of distilled water at room temperature (28±1ºC) in 150 mL cylinder. The time taken for the flour to completely disperse was recorded as the reconstitution time.

Least gelation concentration: Gelation property was determined according to the Coffman and Garcia (1997) method. Sample suspensions of 2-20% (w/w) were prepared in distilled water. Ten millilitres of each of the prepared dispersions was transferred into a test tube. It was heated in a boiling water bath for 1 h, followed by rapid cooling in a bath of cold water. The test tubes were further cooled at 4ºC for 2 h. The least gelation concentration was determined as the concentration when the sample from the inverted test tube did not slip or fall.

Texture: The analysis of texture was carried out with prepared porridges with 10% (w/v) of dry matter using a texturometer (Texturomètre LLOYD, LRX, Ametek, France) which gave:

- Hardness (D) expressed in kilogramme-force (kgf),
- Elasticity (€) expressed in millimetres (mm)
- Sticking capacity (PC) expressed in kilogramme-force (kgf)

Microbiological analysis: The numeration of *E. coli* has been done by the NF ISO 16649-2 method (ISO, 2001). The aerobic flora and coliforms have been counted according to NF EN ISO 21528-2 (ISO, 2004) and NF EN ISO 4833 (ISO, 1991). Mould and yeast were identified by ISO 7954 (ISO, 1987).

Organoleptic test: According to Gomiero *et al.* (2003) the so-called physical attributes of products are key measures of quality, including the sensory or organoleptic parameters such as color, aroma, consistency and texture, plus appearance (size, weight, packaging condition, conditions of use, and hygiene) and overall acceptability using standard methods.

Sensory characteristics of experimental flours were assessed by 73 trained members of the CRSBAN, University of Ouagadougou, (Burkina Faso), and 53 mothers of malnourished children at Centre Médical Saint Camille of Ouagadougou. Fresh samples of cooked porridge prepared by boiling 18% (w/v) slurry of the dough for 15 min were assessed for their color, texture, flavor (aroma), taste and overall acceptability.

The panellists were instructed to sip water before and after assessing each product. The judges recorded sensory characteristics of each sample using 8 - point hedonic scale as described by Ihekoronye and Ngoddy (1985):

where,

8 = like extremely
7 = like very much
6 = like moderately
5 = like slightly
4 = dislike slightly
3 = dislike moderately
2 = dislike very much
1 = dislike extremely

Each treatment was evaluated three times by each panelist.

Statistical analysis: Analysis of variance (ANOVA) and Student's t-test statistics were used for comparing the geometric means of the bacterial counts and the result of other analysis. Chi-square tests were used for comparing the proportions of bacterial counts and the qualitative parameters (organoleptic and sensory parameters). A test of tendency has been carried out for functional analysis. P-values of <0.05 were considered statistically significant. All statistical analyses were carried out using the SPSS software (version 13).

RESULTS AND DISCUSSION

Physico chemical analysis of flours: F3 has the lowest value of moisture (4.0±0.01 g/100), followed by F1 (4.41±0.01) and then F2 (6.05±0.04 g/100), however, these values are higher than the recommended norms ($\leq$5 g) (Table 1). Food commodities which are intended to be used in the preparation of dry weaning foods should be properly dried to reduce eventual development of populations of bacterial and mould, and then only small quantities should be prepared at a time to avoid prolonged storage (WHO, 1998; Solomon, 2005). The high moisture content of the raw material may affect the storage quality of the formula, because high moisture content in foods has been shown to encourage microbial growth (Temple *et al*., 1996). Adequate moisture is an important parameter for local feeding methods in Burkina Faso, because most mothers often prepare large quantities of dry infant food and keep it in containers in order to have spare time and energy for other domestic activities. It is also important to use thick polyethylene for packaging of the samples and reduce relative constant humidity of the storage environment (Ocheme, 2007).

Carbohydrate content (expressed by g/100g of dry matter) in F1 (65.46±0.06), F2 (70.81±0.01) and F3 (64.51±0.01) is higher than the recommended value but no significant difference has been found between the samples. Compared to Misola (63.95±0.04 g) these values are acceptable (Dewey, 2003; Lutter and Dewey, 2003). The analysis showed that F2 had a higher carbohydrate than F1 and F3, which can be explained by cereal composition. F1 is formulated with yellow maize and F3 with millet, while F2 is formulated with rice. Both food commodities have been recommended for infant feeding

Table 1: Physico chemical composition of experimental flours compared to *Misola*

Parameters	Content F1: *Zea mays*	F2: *Oriza sativa*	F3: *Millet*	F4: *Misola*	Recommended* value (g)
Moisture (g/100g DM)	4.41±0.01	6.05±0.04	4.00±0.01	3.30±0.01	≤ 5
Ash (g/100g DM	2.50±0.05	1.53±0.03	2.58±0.05	2.56±0.02	≤ 3
Protein (g/100g DM)	11.72±0.42	9.79±0.43	11.89±0.48	16.8±0.05	≥ 15
Lipids (g/100g DM)	15.91±0.01	11.82±0.02	17.02±0.02	13.39±0.07	10-25
Carbohydrates (g/100g DM)	65.46±0.06	70.81±0.01	64.51±0.01	63.95±0.04	64±4
Energetic value (Kcal/100g DM)	453.07±0.05	424.56±0.03	458.96±0.05	443.51±0.01	400-425

*: (CODEX CAC/GL 08. 1991): Codex alimentarius: Guidelines on formulated supplementary foods for older infants and young children; ND: no detected

Table 2: Minerals composition of experimental flours compared to *Misola*

Analysis	Content F1: *Zea mays*	F2: *Oriza sativa*	F3: *Millet*	F4: *Misola*	Recommended value*
Potassium (mg/100 g)	192±1	112.6±0.5	197.1±0.01	ND	516
Calcium (mg/100 g)	400±1	710±1	520±2	100	500
Magnesium (mg/100 g)	123±20	115±10	190±25	110	76
Iron (mg/100 g)	30.23±10	34.29±13	37.96±12	100	16
Phosphorus (mg/100 g)	251±1	287±5	430±4	260	456
Manganese (μg/100 g)	5.26±0.04	14.39±0.08	18.42±0.21	ND	32
Sodium (mg/100 g)	30±0.0	14±1	40±5	ND	296
Copper (μg/100 g))	9.30±0.3	49.3±0.2	150.7±0.7	0.57	160
Zinc (mg/100 g)	1.77±0.06	2.35±0.02	3.83±0.43	6	3.2

*: (CODEX CAC/GL 08. 1991): Codex alimentarius: Guidelines on Formulated supplementary foods for older infants and young children; ND: no detected

Table 3: Detected microorganisms (UFC/g) in formulated flours and *misola*

Detected microorganisms	Content F1: *Zea mays*	F2: *Oriza sativa*	F3: *Millet*	F4: *Misola*	Recommended value*
Aerobic bacterial	19×10^4	13×10^4	14×10^4	6×10^3	$<10^5$
Escherichia coli	0	0	0	3	<10
Coliforms	0	6×10^2	0	50	$<10^3$
Moulds and yeast	4×10^3	11×10^3	2×10^3	10	$<10^3$

*: (CODEX CAC/GL 08. 1991): Codex alimentarius: Guidelines on formulated supplementary foods for older infants and young children

(Nnam, 2002; Owolabi *et al*., 1996; Bruyeron *et al.*, 2010; Cames *et al*., 2010) due to their positive contribution to carbohydrate nutrition levels.

Lipids (which have been recommended to be around 10-25 g for 100 g (CODEX CAC/GL 08. 1991)) were approximately 17.02±0.02, 11.82±0.02 and 15.91±0.01 g, respectively for F3, F2 and F1 respectively. These values are higher than Misola (13.39±0.07 g), the major complementary flours in Burkina Faso (Table 1). The higher fat content in F3 and F1 can be attributed to the contribution of *Moringa oleifera* and *Cucurbita maxima* seeds (Solomon, 2005).

The high energetic value of the experimental flours (453.07±0.05; 424.56±0.03; 458.96±0.05) can be explained by the high content of carbohydrates and lipids. Compared to Misola (443.51±0.01 kcal), these experimental flours are more energetic (Table 1). The FAO and WHO have recommended that foods fed to infants and children should be energy-dense ones (FAO/WHO, 1998). According to the recommendation, this is necessary because low-energy foods tend to limit total energy intake and the utilization of other nutrients. Energetic diets are necessary for children to cover their need considering the size of their stomachs (Solomon, 2005). High nutrient density is also a desirable characteristic in flours that are used as a base for infant food formulation.

Mineral analysis: The high mineral content of our flours can be attributed to the presence of many ingredients and thorough mixture (Table 2). Deficiencies of sodium, potassium, manganese, and copper can be explained by the inevitable presence of anti-nutritional factors and the poor bioavailability of minerals in plant-based foods (Badamosi *et al*., 1995; Temple *et al*., 1996). Losses during processing also play a vital role in micronutrient deficiency.

Microbiological analysis: The microbiological isolation from each experimental sample is presented in Table 3.

Table 4: Functional properties of experimental flours and *Misola*

Samples/formula	Viscosity (mm/30 sec)	Water absorption capacity (g/g)	Water solubility index (%)	Reconstitution time (s)	Least gelation concentration (%)
F1: *Zea mays*	117±2	2±0.1	95.11±1.1	76±3	9±1.0
F2: *Oriza sativa*	119±2	4±0.4	97.12±2.1	88±2	6±1.9
F3: *Millet*	121±1	1±0.1	95.11±1.0	71±1	7±1.0
F4: *Misola*	120±1	1±0.1	95.10±2.0	72±2	7±0.9

The aerobic bacterial micro flora gradually varied from each sample to other sample (F2<F3<F1). Only F4 and F2 have *E. coli* and coliforms, respectively. Mould and yeast have been present in all samples but F2>F1>F3>F4 although the recommended value is $<10^3$ UFC/g (CODEX, CAC/GL 08, 1991). A wide variety of microorganisms were found associated with the complementary enriched flours in this study. Previous studies also suggest that microorganisms are associated with cereal grains and their products (Odunfa and Adeyele, 1985).

The composition of the micropopulation, as well viable counts obtained, showed a proliferation of coliform, aerobic bacterial, *E. coli*, mould and yeast, but no significant difference has been found between samples using the Student t-test. The contamination can be explained by foodstuffs and possibly manipulation of materials or flour. For example, when water is added to flour, the micro population in the flour begins to grow and metabolize. Yeasts are commonly present as contaminants in cereals and can probably be attributed to the low value of the pH which creates ideal conditions for yeast growth (Serna-Saldivar and Rooney, 1995). The presence of microflora was probably also due to availability of more nutrients for microbial proliferation and enhanced metabolic activities (Mbata *et al*., 2009).

Functional capacity: Viscosity: In terms of viscocity, F3 and F2 did well compared to the recommended value (Mouquet *et al*., 2006). Traoré (2005) and Bruyeron *et al*. (2010) showed that complementary porridge consistency had considerable variation depending on the character, size, proportion of the suspended particles and the consistency of the mixture.

Water absorption capacity: The Water Absorption Capacity (WAC) of the flours ranged from 1 to 4 g/g for F3 and F2, respectively (Table 4). The differences in the water absorption capacities may be explained by their respective contents of hydrophilic constituents such as carbohydrates, which bind more water than protein and lipids. Both carbohydrates and lipids are soluble in water, probably due to the fact that water (as a medium) aids in the breakdown of complexes of starch and protein in to their simpler forms (that is, mono saccharides and amino acids) (Mbaeyi, 2005). It also could be attributed to the high content of lipids and proteins in the flour; Millet flour contains more lipids and proteins than maize and rice flours.

The low water absorption capacity could be also explained by the high content of proteins and fat in millet formula. The water absorption capacity depends on the hydrophobicity of proteins and the polar amino-acids are the preferred sites of the interactions between water and proteins (Kuntz, 1977). When the lipid content is high in the flour, the water absorption decreases because lipids block the polar sites of the proteins attenuating the absorption of water (Sathe and Salunkhe, 1981). So, the differences in the water absorption capacities may be explained by their respective content of hydrophilic constituents such as carbohydrates which bind more water than either protein or lipids (Mbaeyi, 2005).

Water solubility index: Flours showed variation of Water Solubility Index (WSI) from 95.10% for the F4 to a range 97.12% for the F2 (Table 4). The increases were expected, since high molecular weight carbohydrates and proteins were hydrolyzed to simpler more soluble components during the process (Odunfa, 1985; Achinewhu, 1986; Amadi *et al*., 1999).

Reconstitution time: Ease of dispersibility is an important flour property in food formulation (Igene *et al*., 2005). Rice flours showed higher reconstitution times (88 s) ($p<0.05$) than millet flour, whose reconstitution times varied from 71 to 72 s (Table 4). Least gelation concentration: Least Gelation Concentration (LGC) ranged from 7% to 9% (Table 4). When flours that form gels at low concentration are used in infant formula, the diet needs a lot of dilution in order to improve digestibility and this reduces the energy density in relation to volume (Ezeji and Ojimelukwe, 1993). The low level of least gelation concentration was attributed to the possible formation of intermolecular hydrogen bonds between amylase molecules and other proteins present in the cooled gel (Mbaeyi, 2005). According to Ott (1987), the minimal value of the LGC could probably be due to the formation of continuous 3-dimensional solid networks of granules when enmeshed in water. Since starch plays a major role in the gelling

Table 5: Texture characteristics of experimental flours

	F1: *Zea mays*	F2: *Oriza sativa*	F3: *Millet*
Hardness (Kgf)	1.810±0.01	1.690±0.03	1.830±0.02
Elasticity (mm)	0.00017	0.00685	0.1127
Sticking capacity (Kgf)	1.698±0.05	0.189±0.03	3.03±0.02

properties of cereals, the constant LGC of the flours indicate change or not in the carbohydrate content of the flours. Hence the stable least gelation concentration could mean that the starch will be stable during the period of storage (Ott, 1987).

Texture: Table 5 presents the results of the texture of the pulps. Sticking capacity of F3, F2 and F1 were respectively 3.03, 0.189 and 1.698 kgf. The hardness is in the same range, 1.830, 1.690 and 1.810 kgf for F3, F2 and F1 respectively. This could be explained by the botanical origin of cereals and by the effect of starch on texture due to its hydrocolloid properties (Trèche, 1995; Mouquet *et al*., 2006). During gelatinization, the granules inflate due to absorption of water in the polar hydroxyl grouping, which increases viscosity considerably by adherence of the inflated granules (Champ and Faisant, 1992). This could explain the high value of the sticking capacity of the millet flour compared to the other flours.

But, if the heating treatment is prolonged, it can have bursting of the granules, partial hydrolyze and more or less complete dissolution of the constituent molecules which causes the decrease of the viscosity and low values of the elasticity of porridges (Champ and Faisant, 1992).

Degustation: Organoleptic evaluation revealed that the foods were well accepted. The organoleptic evaluation showed that the combinations of cereals and legumes (*Moringa oleifera* and *Curcurbita maxima*), to prepare the food mixtures, were liked by the trained panellists (Table 6). None of the panelists developed any side effects like diarrhea or vomiting, one month after the sensory evaluation.

CONCLUSION

This study revealed that enriched flours formulated from locally available food commodities can meet the macro nutritional needs of infants and children. However, certain aspects like the digestibility and bio-availability of the macronutrients in these local diets need further investigation. Therefore, fortification with appropriate micronutrients or micronutrient-dense foodstuffs will be necessary. The results from this study suggest that proper reformulation and fortification of these local diets can provide nutritious foods that are suitable not only for weaning, but also for more cost effective diets for malnourished children. This is believed to be a practical food-based approach aimed at combating malnutrition among infants and children in Burkina Faso and other developing countries.

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Table 6: Degustation parameters of experimental flours in percentages

	Colour characteristics				Taste characteristics				Aroma characteristics				Appearance characteristics			
Flours	C8	C7	C6	C5	T8	T7	T6	T5	A8	A7	A6	A5	Ap8	Ap7	Ap6	Ap5
F1: *Zea mays*	47.90	41.2	5.4	5.5	28.76	43.84	13.7	13.7	27.4	46.50	11	15.1	43.8	45.2	10.99	0.01
F2: *Oriza sativa*	22.00	41.0	25.0	12.0	37.60	27.4	14.0	21.0	19.0	34.00	21	26.0	16.2	44.0	26.00	13.8
F3: *Millet*	26.00	33.0	22.0	19.0	38.00	29.0	11.0	22.0	32.0	33.00	8	27.0	18.0	34.2	19.20	28.6

8 = like extremely; 7 = like very much; 6 = like moderately; 5 = like slightly

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