LWT - Food Science and Technology 98 (2018) 148–153

Contents lists available at ScienceDirect

LWT - Food Science and Technology

journal homepage: www.elsevier.com/locate/lwt

Formula optimization approach for an alternative Ready-to-Use Therapeutic Food

Vincenzo Armini[a], Nicoletta A. Miele[b,*], Matteo Albero[a], Raffaele Sacchi[a], Silvana Cavella[a,b]

[a] Department of Agricultural Sciences, Unit of Food Science and Technology - University of Naples Federico II, 80055, Portici, Italy
[b] Center of Food Innovation and Development in the Food Industry, University of Naples Federico II, 80055, Portici, Italy

ARTICLE INFO

Keywords:
RUTF
Severe acute malnutrition
Community-based management of acute malnutrition
Particle size distribution
Viscosity

ABSTRACT

Ready-to-Use Therapeutic Food (RUTF) is an energy-dense, micronutrient-enriched paste used for the Community-based Management of Acute Malnutrition (CMAM) in under-five children of low-income countries. Alternative recipes have to reach a decrease of production costs and the use of local staple ingredients, enforcing quality and acceptability of the product. This work consisted on an alternative RUTF formula optimization, with the aim to have a set of optimized creams suitable for child feeding, based on local and cheap ingredients. A response surface D-optimal design was carried out, adopting United Nations Children's Fund (UNICEF) constraints for RUTF formula. The creams showed a time-independent pseudoplastic behavior with n and K in the range 0.38–0.45 and 35–110 Pa·s^n, respectively. The Particle Size Distribution (PSD) curves, as determined by laser diffractometry, were mainly unimodal, with 90% percentiles (D_{90}) varying from 40 to 140 µm. Response variables better explained through chosen models were D_{90} and K parameter. Thanks to formula optimization approach it has been verified that the consistency and the particle size are strongly affected by the ingredient formulation. The best formulation of model RUTF was found, through the desirability function, imposing as constraints the minimization of both D_{90} and K index.

1. Introduction

Wasting affects about 51 million children, while severe wasting almost 17 million of them (FAO, IFAD, UNICEF, WFP, & WHO, 2017). Moreover, it is estimated that 5.9 million children under five years old die each year and half of them due to malnutrition (UNICEF, 2016).

Critical socio-environmental conditions (high temperatures, poor general hygiene and lack of drinking water) favor the spread of endemic diseases and amplify the issues of malnutrition. To overcome those difficulties, Ready-to-Use Therapeutic Foods (RUTFs), namely also "Quick Use Therapeutic Foods" have been conceived. RUTF is an energy-dense, micronutrient-enriched paste used for the Community-based Management of Acute Malnutrition (CMAM) in under-five children of low-income countries. These products can be given to children without clinical complications directly at home, avoiding hospitalization. RUTFs must provide 200 kcal/kg/day in order to reach a rapid weight increase and to achieve acceptable physical recovery within 6–10 wk (Collins et al., 2006; Santini, Novellino, Armini, & Ritieni, 2013).

RUTFs are characterized by a low water activity ($a_w < 0.6$) that provides excellent microbiological stability also at room temperature. The oxidation stability of RUTFs is obtained packaging the product in modified atmosphere (100% N_2), ensuring a shelf life of 24 months (Lloyd, Hess, & Drake, 2009), with a film of triglycerides that protect the vitamin components from oxidation (Briend, 2001).

RUTF may be considered as a biphasic cream consisting of a mixture of solid powders dispersed in a hydrophobic liquid phase (Glicerina, Balestra, Pinnavaia, Dalla Rosa, & Romani, 2013), commonly a vegetable oil. The major issue of polyunsaturated fat-based creams is lipid oxidation during refining, due to the temperature increase and oxygen availability, which can negatively influence both the sensory and nutritional properties of the final product (Manary, 2006).

Cream granulometry should be as fine as possible to guarantee a high homogeneity and hinder phase separation, taking into account an acceptable swallow consistency (Afoakwa, Paterson, & Fowler, 2008). Therefore, a reduction of the solid particle sizes, completely covered with fat phase, is desirable (Petković, Pajin, & Tomić, 2013). Solid powder refining is mainly carried out with roll refiners, typical of the chocolate industry, or with stirred ball mills, recycling the product through the ball mill several times (Alamprese, Datei, & Semeraro,

* Corresponding author. Center of Food Innovation and Development in the Food Industry, University of Naples, Federico II. Via Università 133, 80055, Portici, Italy.

E-mail address: nicolettaantonella.miele@unina.it (N.A. Miele).

https://doi.org/10.1016/j.lwt.2018.08.038
Received 25 May 2018; Received in revised form 26 July 2018; Accepted 14 August 2018
Available online 18 August 2018
0023-6438/

2007; Fidaleo et al., 2017; Lucisano, Casiraghi, & Mariotti, 2006). As the granulometry decreases, the consistency of the cream improves and phase separation slows down (Black, Pahulu, & Dunn, 2009). A cream with an optimal consistency means a more squeezable and easier to swallow product, fundamental feature of RUTFs (Ali et al., 2013).

The structure of a cream, as its rheological behavior and texture, is affected both by process conditions (temperature, refining spread and time) (Petković et al., 2013) and by formulation (Glicerina, Balestra, Dalla Rosa, & Romani., 2016; Lončarević et al., 2016).

Actual RUTF mainstream formulation is affected by some ingredient issues, as high cost of skimmed milk powder, nutritional properties of palm oil, allergenic power of peanuts.

Alternative RUTF recipes should be defined) to reduce production costs, ii) by using local ingredients available in low-income countries, iii) by improving quality and acceptability. As main ingredients, dehulled and roasted sorghum and soya could be used as source of proteins, icing sugar as glucose source, sweetening and bulking agent, sunflower oil for its availability, technological and nutritional properties. In order to guarantee an adequate intake of micronutrients, such as vitamins and minerals, *Arthrospira maxima* (commonly called Spirulina) microalgae dried powder should be considered. In fact, the World Health Organization (WHO) has called Spirulina as one of the greatest superfoods on earth (Chacon-Lee & Marino, 2010), due to the easy bioavailability of its nutrients, including minerals.

The aim of this study was to define the formulation of an alternative RUTF with nutritional values responding to the needs of malnourished children, through a formula optimization approach.

2. Materials and methods

2.1. Materials

For RUTF formula optimization, the following ingredients were used: sunflower oil (Grazia, Lucca, Italy) and soy lecithin (ACEF, Piacenza, Italy), as lipidic phase, dehulled and roasted soy flour (Consorzio Agrario dell'Emilia Romagna, Bologna, Italy) and dehulled and roasted sorghum flour (Consorzio Agrario dell'Emilia Romagna, Bologna, Italy), as flour mix, and icing sugar (Eridania, Bologna, Italy). Microalgae Spirulina dried powder was also used (produced in CAISIAL-University of Naples, Portici, Italy). All the powders presented a Particle Size Distribution lower than 250 μm and a moisture content lower than 1 g/100 g. The characteristics of new formulations were compared to that of a widely diffused commercial RUTF (Plumpy' Nut®, Nutriset, Malaunay - France). The main ingredients of Plumpy' Nut® are peanut butter, flour, sucrose, palm oil, sunflower oil, skimmed powdered milk, mineral salts and vitamins (A, C, D, E, B1, B2, B6, B12, biotin, folic acid, pantothenic acid, and niacin), and the macronutrients average content can be indicated as lipids 36%, proteins 14%, carbohydrates about 43% (500 kcal per 92 g package) (Santini et al., 2013).

2.2. Experimental design

2.2.1. Experimental design

A D-optimal mixture design was used (Miele, Di Monaco, Masi, & Cavella, 2015). Only one ingredient was constant, dried Spirulina powder, representing only 3 g/100 g of the mixture to ensure a good nutritional intake and, contemporary, to avoid hypervitaminosis. The variable ingredients (97 g/100 g) consisted of flour (x1), lipidic phase (x2) and icing sugar (x3). The proportions of each ingredient were expressed as a g/100 g of the mixture, and for each treatment combination, the sum of the component weights was equal to one hundred grams, where:

$$x1 + \times 2 + \times 3 = 100 \quad (2.1)$$

Preliminary tests of pastry-mixing workability and specific nutritional requirements for RUTF (Santini et al., 2013) allowed to set the following ranges for each ingredient: flour mix (x1) 30–40 g/100 g; lipidic phase (x2) 25–35 g/100 g and icing sugar (x3) 25–35 g/100 g.

A Cubic model (Gacula, 1993) was used and 20 experimental points were determined, 5 points were replications. In Table 1 oil/powder and oil/icing sugar ratios are reported for each formulation instead of the ingredient concentration.

Each formulation was replicated three times.

2.2.2. Sample preparation

For cream production, a stirred ball mill was used (model PM 200, Retsch, Haan, Germany), equipped with two jars (250 mL). 5 spheres of 2 cm diameter and 4 spheres of 1 cm diameter were used. Ingredient weight was set at 50 g, according to manual specifications of the instrument. Through preliminary experiments, the optimal refining conditions were determined. Optimal speed rate and optimal time were set using both the higher and lower oil/powder ratio creams, measuring

Table 1
Oil/powder ratio, oil/icing sugar ratio, mean values of D_{10}, D_{50}, D_{90}, K and n indexes, for each RUTF formulation.

Formulation	Oil/powder ratio	Oil/icing sugar ratio	D_{10} (μm)	D_{50} (μm)	D_{90} (μm)	K ($Pa\cdot s^n$)	n
1	0.47	1.01	2.86 ± 0.03[g]	9.98 ± 0.2018[cde]	48.16 ± 4.1918[bc]	57.57 ± 2.3328[cdef]	0.47 ± 0.0129[cdefg]
2	0.51	1.00	2.74 ± 0.08[b]	9.90 ± 0.3213[cde]	42.45 ± 6.1413[c]	53.69 ± 5.2766[cde]	0.40 ± 0.0273[abc]
3	0.48	1.21	3.06 ± 0.03[l]	10.68 ± 0.1473[f]	59.27 ± 3.1650[de]	75.20 ± 4.5529[g]	0.42 ± 0.0042[abcd]
4	0.42	0.89	2.90 ± 0.0336[h]	10.16 ± 0.1830[de]	52.22 ± 4.9143[cd]	107.41 ± 2.1337[i]	0.40 ± 0.0048[ab]
5	0.51	1.13	2.78 ± 0.0336[cd]	9.66 ± 0.2120[bc]	45.30 ± 3.5422[bc]	60.06 ± 4.5207[cdef]	0.40 ± 0.0167[ab]
6	0.45	0.91	2.80 ± 0.0246[de]	9.96 ± 0.1360[cde]	53.09 ± 3.7849[cd]	70.43 ± 2.3203[fg]	0.42 ± 0.0113[abcde]
7	0.42	1.05	3.00 ± 0.0639[i]	10.22 ± 0.1908[de]	52.70 ± 3.2274[cd]	66.5 ± 3.1061[efg]	0.38 ± 0.0729[a]
8	0.32	0.71	3.73 ± 0.0866[a]	19.21 ± 2.0395[l]	128.75 ± 41.1402[i]	110.76 ± 15.9953[i]	0.45 ± 0.0708 [abcdefg]
9	0.51	1.19	2.84 ± 0.0487[fg]	9.81 ± 0.1573[cd]	47.55 ± 2.9332[bc]	47.36 ± 4.6889[abc]	0.44 ± 0.0119[abcdefg]
10	0.44	1.00	2.93 ± 0.0742[h]	10.15 ± 0.2826[de]	52.71 ± 5.3579[cd]	63.1 ± 6.1226[defg]	0.44 ± 0.0164 [abcdefg]
11	0.51	1.40	3.09 ± 0.0305[l]	10.34 ± 0.1353[ef]	41.83 ± 3.6321[bc]	39.61 ± 1.6202[a]	0.46 ± 0.0076[bcdefg]
12	0.37	0.87	3.67 ± 0.0378[n]	16.27 ± 0.6976[i]	95.73 ± 8.5204[g]	56.66 ± 18.6125[cdef]	0.49 ± 0.0321[fg]
13	0.51	1.40	2.76 ± 0.0210[bc]	9.10 ± 0.1673[a]	35.78 ± 2.8833[a]	35.75 ± 2.1067[ab]	0.47 ± 0.0102[defg]
14	0.45	0.91	2.92 ± 0.0514[h]	12.15 ± 0.3692[g]	66.39 ± 6.9962[ef]	60.35 ± 2.7107[cdef]	0.50 ± 0.0129[g]
15	0.47	1.11	2.74 ± 0.0309[b]	9.75 ± 0.3205[bcd]	48.14 ± 7.6814[bc]	50.89 ± 3.6621[bcd]	0.47 ± 0.0106[cdefg]
16	0.37	0.87	3.64 ± 0.0920[n]	15.82 ± 1.4398[h]	92.12 ± 25.6673[g]	98.65 ± 12.6106[h]	0.42 ± 0.0687[abcde]
17	0.32	0.71	3.71 ± 0.0800[a]	18.87 ± 1.1829[l]	117.05 ± 12.3266[h]	112.94 ± 7.7114[i]	0.48 ± 0.0644[defg]
18	0.51	1.00	2.82 ± 0.0254[ef]	9.86 ± 0.1531[cde]	45.76 ± 3.1505[bc]	48.65 ± 3.1127[abc]	0.43 ± 0.0103[abcdef]
19	0.51	1.06	2.66 ± 0.0226[a]	9.35 ± 0.0955[ab]	40.24 ± 1.2746[ab]	38.67 ± 4.1995[ab]	0.44 ± 0.0177 [abcdefg]
20	0.37	0.80	3.18 ± 0.0322[m]	11.95 ± 0.2724[g]	69.33 ± 8.1556[f]	69.95 ± 3.8909[fg]	0.49 ± 0.0136[efg]

D_{10}, D_{50}, D_{90}, K and n indexes represent means ± standard deviations of three replicated determinations. Values in the same column followed by different letters differ significantly at $P < 0.05$ level (Duncan's method).