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The "Pappa di Parma" integrated approach against moderate acute malnutrition

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ABSTRACT

The use of Ready-to-Use Therapeutic Foods (RUTFs) is not a sustainable strategy to treat child moderate acute malnutrition due to its high cost and unfamiliarity.

An integrated multidisciplinary approach called "Pappa di Parma" was used to develop, characterize and introduce alternative sustainable and energy-dense meals against malnutrition.

Six formulations were developed by using basic accessible technologies and locally available ingredients (Tanzania), a daily portion of which meets RUTFs macronutrient requirements and most micronutrients RNI. Quality characterization, rheological properties and shelf-stability of *formulae* were assessed under different storage conditions disclosing the suitability and stability of *no-water formulae* in all tested storage conditions for almost under three months. Moreover, the cultural acceptance and the economical sustainability through the implementation in Tanzania were also evaluated. Overall, this study confirmed the "Pappa di Parma" approach as a valid starting point to sustainable alternatives to RUTFs, tailored to specific agricultural and socio-economic contexts.

1. Introduction

Malnutrition is one of the primary causes of child mortality according to the WHO (World Health Organization) (2019). Globally, in 2018, almost 200 million children under 5 suffered from stunting and/or wasting, and at least 340 million from vitamin and mineral deficiencies (UNICEF, 2019).

Child malnutrition is extremely common in Middle and Eastern African states. In Tanzania alone nearly 40% of preschool children are malnourished (UNICEF, 2019), with 34% suffering from stunting and 6% from wasting.

In combatting this dramatic burden, significant breakthroughs have been made in treating wasting. The best-known approach is the *Community Management of Acute Malnutrition* (CMAM) that empowers families to treat acute malnutrition at home usually using specially formulated lipid-based foods in supplementary or complementary doses, namely Ready-To-Use Therapeutic Foods (RUTFs) (Gera, Pena-Rosas, Boy-Mena, & Sachdev, 2017; Lazzerini, Rubert, & Pani, 2013; Manary, 2006; UNICEF, 2019). RUTFs are safe, palatable, high-energy foods with appropriate amounts of nutrients, similar in composition to therapeutic hospital diets (WHO, UNICEF, WFP and UN System Standing Committee on Nutrition, 2007). Since hospitalisation is not always advantageous, especially in low-income rural scenarios, RUTFs frequently offer an alternative for home interventions. A household RUTF therapy provides about 200 kcal/kg of body weight/day proving efficacious in treating both Severe Acute Malnutrition (SAM) (Armini, Miele, Albero, Sacchi, & Cavella, 2018; Guimón & Guimón, 2012; Santini, Novellino, Armini, & Ritieni, 2013) and Moderate Acute Malnutrition (MAM), in appropriate dosages (Bharaniidharan & Reshmi, 2019; Briend et al., 2015; Gera et al., 2017). However, RUTFs are not always appropriate to manage MAM, due to the high cost and unfamiliarity (Annan, Webb, & Brown, 2015). Indeed, the use of non-local ingredients and non-involving of the community are the main causes of RUTFs' failure among mothers of malnourished children (Ali et al., 2013; Dube et al., 2009; Guimón & Guimón, 2012; Vanelli et al., 2014). Nutritional education is vital to help mothers prepare meals (Ashworth & Ferguson, 2009; Vanelli et al., 2014), while satisfying children's sensory preferences is fundamental in nutrition interventions (Rakotosamimanana & De Kock, 2020).

Abbreviations: CMAM, community-management of acute malnutrition; RUTF, ready-to-use therapeutic food; SAM, severe acute malnutrition; MAM, moderate acute malnutrition; ASF, animal source food; RNI, recommended nutrient intakes; AI, adequate intakes; EFSA, European Food Safety Authority; RDA, recommended daily allowance.

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Therefore, community engagement is vital in CMAM (Ali et al., 2013; Dube et al., 2009; Guimón & Guimón, 2012; Vanelli et al., 2014).

Given the above, research has sought alternative foods which are potentially therapeutic against wasting, using ingredients accessible to families (Brixi, 2018; Collins & Henry, 2004; Dube et al., 2009; Lazzerini et al., 2013; Vanelli et al., 2014; Weber et al., 2017).

A hand-made supplementary food known as "Pappa di Parma", prepared encouraging the active involvement of families and with local ingredients, proved effective against MAM in Sierra Leone (Vanelli et al., 2014). Nonetheless, the authors concluded that substituting milk powder and multivitamin mix with sustainable alternatives would enhance local feasibility.

In this context, the aim of this work was to design new formulations to improve and tailor "Pappa di Parma" to specific agricultural and socio-economic contexts. In particular, "Pappa di Parma" integrated approach aimed to develop, improve and introduce "Pappa di Parma" as an alternative, innovative, sustainable, energy-dense meal against MAM in 6–60-month infants in Tanzania. The products' shelf-stability and consumption appropriateness were also assessed under different storage conditions.

2. Materials and methods

The experimental scheme was implemented in the village of Mvimwa (Rukwa Region, Tanzania), a poor area at 60 km from the city of Sumbawanga. In 2015, more than 600,000 Tanzanian children under 5 years of age suffered from acute malnutrition, of which 500,000 were moderate cases (UNICEF, 2020). At Mvimwa's Benedictine Abbey, around 100 monks support local people by creating work, healthcare and education programmes.

2.1. Formulae development

2.1.1. Ingredient database

Firstly, a list of locally available ingredients was compiled from food composition tables from national agricultural reports (FAOSTAT) [Tanzania Food Composition Table (Lukmanji et al., 2008); West African Food Composition Table (FAO, 2012)], and communications collected in loco. The food/ingredients identified were grouped in different categories as follows: fruit and vegetables, legumes, starches (roots, tubers and cereals), seeds and nuts, fats and oils, dairy, meat-based ingredients, fish and others.

Meats were excluded, since they are not commonly consumed being expensive, thus not widely accessible. Instead, fish was included being an accessible animal-source food (ASF) in low-income countries and a fundamental component of food-based strategies to fight nutrient deficiency (Roos, Wahab, Chamnan, & Thilsted, 2007).

To complete the database of food locally available, nutritional information on each food/ingredient was obtained from local databases integrated with quantitative information from the Food Composition Table for Use in Africa, INFOODS/FAO (Woot-Tsuen, Busson, & Jardin, 1968) and the USDA, 2008.

2.1.2. Nutritional objectives

The nutritional composition of the food was defined with a number of nutritional and technological constraints to meet:

- A daily serving size equal to 200 kcal/kg/day calculated considering the energy requirements of malnourished children between 6 and 60 months (Ashworth, Khanum, Jackson, & Schofiel, 2003), in agreement with Vanelli et al. (2014).
- A nutritional composition in terms of percentage energy content from lipids and proteins per daily serving size established to meet the RUTF requirements of the joint statement from the WHO, WHO, UNICEF, WFP and UN System Standing Committee on Nutrition, 2007; Table 1). To avoid using industrial micronutrients preparations, when RUTF requirements could not be met, minimum tolerance values per day were used for micronutrients in line with Recommended Nutrient Intakes (RNI) specified by WHO and FAO, 2004. When the latter were not available, the Population Reference Intakes (PRI) or Adequate Intakes (AI) issued by EFSA, were used (EFSA, 2017). For these, they have been considered the values for 4- to 6-year-old children since they represent the highest available for our target population (6–60 months) (Table 1).
- The presence of carbohydrate-rich foods (cereals, roots and tubers), proteins from plants or animal-based staples (legumes, groundnuts, ASF) and lipids to increase energy concentration and workability and palatability to the meal. Moreover, the presence of fruit and vegetables mainly for micronutrients was also searched for. Additionally, sugar was deemed mandatory to achieve the energy target and offer children a pleasant flavour.

Table 1
Energy and nutrient composition of Ready-to-use therapeutic food (RUTF) (WHO, UNICEF, WFP and UN System Standing Committee on Nutrition, 2007) and minimum tolerance assumed for vitamins and minerals daily intake referred to 4–6 age child. The minimum tolerance was established considering the vitamin and mineral recommended nutrient intakes (RNI) specified by (WHO and FAO, 2004) and the adequate intakes (AI) released by the European Food Safety Authority (EFSA, 2017). RE = retinol equivalent; DFE = dietary folate equivalents; NE = niacin equivalents. a-TE: a-tocopherol.

	RUTF values (100 g)			Minimum tolerance values (per day)	
Component	Min	Max		WHO & FAO (2004)	EFSA (2017)
Energy	520	550	kcal	/	/
Proteins	10	12	% total energy	/	/
Lipids	45	60	% total energy	/	/
Sodium	/	290	mg	/	/
Potassium	1100	1400	mg	/	1100 mg/day
Calcium	300	600	mg	600 mg/day	
Phosphorus	300	600	mg	/	440 mg/day
Magnesium	80	140	mg	76 mg/day	
Iron	10	14	mg	6.3	
Zinc	11	14	mg	4.8	
Copper	1.4	1.8	mg	/	1 mg/day
Vitamin A (RE)	800	1100	μg	450 μg RE/day*	
Vitamin C	50	/	mg	30 mg/day	
Vitamin D	15	20	μg	5 μg/day	
α-tocopherol	20	/	mg	5 mg α-TE/day	
Thiamin	0.5	/	mg	0.6 mg/day	
Riboflavin	1.6	/	mg	0.6 mg/day	
Niacin (NE)	5	/	mg	8 mg NE/day	
Pantothenic acid	3	/	mg	3 mg/day	
Vitamin B6	0.6	/	mg	0.6 mg/day	
Folate (DFE)	200	/	μg	200 μg DFE/day	
Cobalamin	1.6	/	μg	1.2 μg/day	

* Recommended safe intake.

Besides nutrient and technological factors, safety-related features were also further constraints for meal formulation optimization.

2.2. Benchtop production

Development and optimisation of several "Pappa di Parma" *formulae* were carried out at the Food and Drug Department laboratories of the University of Parma (Italy). Depending on availability, accessibility and affiliation with Italian customs, ingredients were purchased from Italian retail chains (CONAD), Italian organic stores (EcorNaturaSì Spa; Tibiona online store), or African grocery stores.

A benchtop "Pappa di Parma" production sought to replicate domestic food preparation in African countries. Preliminary experiments (>20) allowed to select the type and amount of ingredients, with appropriate pre-treatments and blending in order to obtain a homogeneous meal, pleasant for children in taste and texture, while meeting the pre-established nutritional requirements.

2.3. Rheological properties

A stress-controlled rheometer (MCR 102, Anton-Paar GmbH, Graz, Austria) with a parallel plate (25 mm diameter, depth 0.5 mm) based on the Peltier system with a solvent trap to avoid moisture loss, were used to measure viscosity and flow behaviour of different meals. For each test, a sample of approximately 4 mL was placed between the plates (2 mm gap) and allowed to relax for 30 s before analysis. Shear stress (τ) and apparent viscosity (η) were evaluated as a function of shear rate ($\dot{\gamma}$) from 0.1 to 18.5 s^{-1}. To analyse the effect of temperature on rheological behaviour and to simulate Sub-Saharan African climatic conditions, measurements were performed both at 25 °C and 40 °C. Commercial fruit-based (F) and meat-based (M) infant foods were taken as reference samples. Flow curves were fitted to the Herschel-Bulkley rheological model (Eq. 1) using SigmaPlot v. 12.5 software (Systat Software Inc., USA) to obtain rheological (τ_0, n and K) and statistical parameters (R^2) (Ahmed & Ramaswamy, 2006):

$$\tau = \tau_0 + K\,\dot{\gamma}^n \quad (1)$$

where τ_0 (Pa) is yield stress, K is the consistency index (Pa•s^n), and n is the flow behaviour index.

2.4. Physicochemical properties

After preparation, "Pappa di Parma" *formulae* were cooled at room temperature for 1 h and characterized for physicochemical properties (t0). The meals were divided into two main groups: (i) *water-formulae*, prepared with fresh ingredients or ones needing re-hydration, and (ii) *no-water formulae*, without added water. To investigate shelf-stability in a simulation of typical Tanzanian food production, *no-water formulae* were packed in polyethylene bags and stored for a period of 90 days (t90) under the following conditions (i) at 25 °C, vacuum-sealed, dark; (ii) at 25 °C, light; (iii) at 40 °C, light. The *formulae* were characterized at t0 (*water-formulae* and *no-water formulae*) and and t90 (*no-water formulae*) for their moisture content [MC, g water/100 g sample; by weight loss after forced-air oven drying (ISCO NSV 9035, ISCO, Italy)], water activity [a_w; at 25 °C with Aqualab 4 TE (Decagon Devices, Inc., USA)] and pH (FiveEasy, Mettler-Toledo, LLC, USA). The pH of *no-water formulae* was measured by dispersing 1 g of sample in 6 mL of distilled water. The pH values were calculated using the Dilution Equation (Eq. 2):

$$M1 * V1 = M2 * X2 \quad (2)$$

where: *M1*: H_3O^+ ions concentration before water suspension; *V1*: initial volume (mL); *M2*: H_3O^+ ions concentration after water suspension; *V2*: final volume (mL).

Colour of *formulae* was also measured using a CIELAB colorimeter (CM 2600d, Minolta Co., Japan) under standard illuminant D65. L^* (Lightness), a^* (degree of redness) and b^* (degree of yellowness) were measured using a 10° position of the standard observer. Ten determinations were taken for each sample at each storage time. Differences in colour between *no-water* samples during storage (t0 and t90) were evaluated using a ΔE value calculated as follows (Eq. 3):

$$\Delta E = \left[(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2 \right]^{1/2} \quad (3)$$

All analyses were performed at least in triplicate for each storage period and condition.

2.5. Lipid oxidation

Measurement of lipid oxidation was performed after lipid extraction (EN ISO 659:2009, 2009).

Peroxide value (PV) of *no-water formulae* was determined by iodometric titration (EEC Regulation 2568/91, 1991). To verify the products' lipid oxidation during storage in the three aforementioned conditions, PV was measured over three months' storage (t0, t2, t7, t15, t50, t90). Three determinations were taken for each sample at each storage time.

2.6. Search for ingredients at local markets and preparation

In order to implement "Pappa di Parma" in Tanzania, a preliminary investigation of local availability, affordability and costs of the ingredients to prepare the meals was carried out at the most important trade centres of the closest city, Sumbawanga. Then, meals were prepared in the Mvimwa Abbey kitchen using basic available technology.

2.7. Satisfaction questionnaire

Meals were provided to 289 children (mean age ± SD: 22.1 ± 16.6 months, 48% females) from villages around Mvimwa Abbey. Children were recruited during medical visits at the dispensary by local monks and medical staff. The involvement of monks and medical personnel as trusted effective intermediaries encouraged the families' engagement and consensual participation in the survey. Moreover, their linguistic and healthcare mediation also ensured that the families received correct information and that the meals were safely administered to the children (Rakotosamimanana & De Kock, 2020). After preparing the meals, families were recruited at the dispensary for a Satisfaction Interview. Firstly, monks used local language to explain objectives of the project and provide proper information about ingredients and meals preparation to the families. After tasting a half-spoonful of food, meal taste and acceptability was assessed by asking the children whether they liked it (closed Yes/No format) or, in the case of the youngest children unable to respond autonomously, by asking their mothers to interpret the children's perceptions. In addition, mothers were questioned about (i) their willingness to prepare "Pappa di Parma" by themselves, and (ii) their willingness to buy "Pappa di Parma" if available on the market, from a school or dispensary, using a closed Yes/No format.

2.8. Statistical analysis

A one-way variance analysis (ANOVA) and Duncan's post hoc test were used to establish significant differences between the mean physicochemical values. For each rheological parameter obtained from the data fitting, significant differences at 25 °C and 40 °C were assessed based on Student's Distribution. In addition, a Chi-square test was used to explore the association between categorical variables referring to satisfaction data. The statistical analysis was performed at the 0.05 significance level using SPSS statistical software (Version 25.0, IBM SPSS Inc., Armonk, New York, USA). Values were expressed as mean ± standard deviation (SD) for continuous variables or as pure number and percentage in the case of categorical variables.

3. Results and discussion

3.1. Formulation and nutritional composition

Six candidate "Pappa di Parma" *formulae* were developed, varying the type and quantity of ingredients and/or proportions (Table 2). Three of them included water as *formula* WMP (water-milk power), WCB (water-corn-bean flour), WSB (water-sesame-bean flour). Other three included no water: NWP (no water-peanut flour), NWS (no water-soya flour), and NWF (no water-fish flour).

Table 2
"Pappa di Parma" *formulae* (g/100 g). WMP: water-milk power formula; WCB: water-corn-bean flours; WSB: water-sesame-bean flour formula; NWP: no water-peanuts flour formula; NWS: no water-soya flour formula; NWF: no water-fish flour formula. n.a.: not available data.

Category	Ingredient	Cost	WMP	WCB	WSB	NWP	NWS	NWF
Fats and oils	Palm oil	1.31 $/L	9	8.5	6.6	8.9	12.8	12.5
	Sunflower seed oil	1.74 $/L	/	/	/	8.9	10.3	12.5
	Sesame butter	/	/	/	/	15.6	17.9	15
Seeds and nuts	Sunflower seed flour	/	/	/	/	/	/	10
	Sunflower seeds	0.87 $/Kg	16	/	/	/	/	/
	Peanuts	1.04 $/Kg	9	12.8	8.9	/	/	/
	Peanuts flour	n.a.	/	/	/	20	/	/
	Sesame seeds	1.74 $/Kg	/	/	11.1	15.5	/	/
Legumes	Bean flour	0.65 $/Kg	/	25.5	24.5	/	/	/
	Soya flour	1.74 $/Kg	/	/	/	/	25.6	/
Starchy foods and cereals	Cassava flour	1.74 $/Kg	16	8.5	11.1	/	/	/
	Corn flour	0.43 $/Kg	/	10.6	/	/	/	/
Animal-based products	Milk powder	11.31 $/Kg	22.7	/	/	/	/	/
	Fish flour	n.a.	/	/	/	/	/	12.5
Fruits and vegetables	Avocado	0.22 $/piece	11.3	21.3	20	/	/	/
	Baobab	1.74 $/Kg	/	/	/	8.9	10.3	7.5
Others	Sugar	1.22 $/Kg	16	12.8	17.8	22.2	23.1	30

All formulations contained palm oil (6.6–12.8%) which gave the product a creamy texture. *No-water formulae* also contained sunflower seed oil (8.9–12.5%) and sesame butter (15.0–17.9%) as a lipid phase, lending a more pleasant flavour. Milk powder (22.7%) and fish flour (12.5%) were the only two ASFs used. All "Pappa di Parma" *formulae* contained sugar (12.8–30.0%) to provide a sweet taste, while avocado (11.3–20.0%) and baobab pulp powder (7.5–10.3%) were the two fruits used.

The nutritional composition of the "Pappa di Parma" *formulae* is shown in Table 3 and SM1.

Energy content varied between 406 and 539 kcal/100 g. Only NWS *formula* successfully achieved typical RUTF energy content, while NWP and NWF reached a value remarkably close to it (−1.6 kcal/100 g and −0.4 kcal/100 g, respectively). However, all "Pappa di Parma" *formulae* had an energy content providing 200 kcal/kg of body weight/day in line with WHO recommendations (Ashworth et al., 2003). Out of the total energy content, 10.0–12.0% derived from proteins and 52.5–63.0% from lipids, in accordance with the optimal macronutrient composition of a RUTF (WHO, UNICEF, WFP and UN System Standing Committee on Nutrition, 2007). Similarly, the Na content of all *formulae* respected the maximum level set for RUTF composition. RUTF content values were also achieved for some minerals in certain preparations: Ca in NWP and NWF, P in WMP and NWF, Mg in WMP, NWP, NWS and NWF, and Fe in WSB. However, it should be emphasised that RUTFs provide adequate nutrients for SAM subjects, while our targets were MAM children, for whom a standard RUTF can provide excess nutrients (De Pee & Bloem, 2009).

By comparing the energy-parity formulations (2000 kcal) provided by a daily portion (satisfying the maximum energy requirement of 200 kcal/kg of body weight/day (Ashworth et al., 2003) for a 10 kg undernourished child), it was noted that the amount of P, Mg, Fe, and vitamins A, C, E and B6 was higher than the RNIs specified by WHO and FAO (WHO and FAO, 2004) and the AIs issued by EFSA (EFSA, 2017) in all six preparations. Instead, the amount of Ca, K, Zn, Cu, and vitamins B1, B2 and B3 was above the reference levels in five out of six *formulae*. Daily requirements of pantothenic acid (B5) were only covered by WMP, folate requirements by NWS. Cobalamin met the recommendations only in the *formulae* containing ASFs, i.e. WMP and NWF, as expected. As for vitamin D, the minimum value was not met by any of the "Pappa di Parma" *formulae* due to the absence or very low presence of ASFs. However, it is worth recalling that apart from the pre-formed vitamin provided by ASFs, vitamin D can be synthesised in the skin by exposure to sunlight. In the majority of countries lying around the equator, like Tanzania, endogenous synthesis may be the main source of this vitamin, with skin synthesis estimated to provide around 10 mg/day (WHO and FAO, 2004).

Although the amounts of certain nutrients provided by "Pappa di Parma" *formulae* were much higher than the RDA, we must recall that, during the design, the nutrient content was assumed not to vary consequent to the technological processes. If this might be plausible (although not certain) for *no-water formulae*, it was presumed that a loss of some of the micronutrients of *water formulae* due to the ingredients processing during meal preparation may have occurred. Moreover, discrepancies which arose for some nutrients with respect to the reference values may be due to incompleteness of the reference nutritional databases and the need to respond to technological and sensory criteria using only accessible raw materials. Furthermore, criticalities also arose from the reduced inclusion of ASFs, which are fundamental sources of nutrients seldom consumed in low-income countries owing to cost or inaccessibility. Wherever necessary, the intake of certain micronutrients can be increased with small meals given throughout a child's food day. It should be remembered, in fact, that "Pappa di Parma" is a specially formulated supplementary meal to be consumed at home as a part of children's food day, which can include other food (e.g. breastmilk, fruit and vegetables) to complete nutritional needs. Moreover, it is worth emphasizing that food fortification (e.g. wheat flour fortified with 0.02 mg/kg cobalamin, 2 mg/kg folic acid, 50 mg/kg zinc oxide and 38 mg/kg sodium-iron EDTA commonly available at local Tanzanian markets) is a widespread basic alternative in low-income countries, complementing food-based approaches to satisfy people's nutritional needs (WHO and FAO, 2004).

3.2. Rheological characterization

Flow curves of "Pappa di Parma" *formulae* in comparison with commercial meat (M) and fruit (F) infant foods at 25 °C and 40 °C are plotted in Fig. 1. With the shear rate increase, the shear stress increased in a larger amount in all the meals tested indicating non-Newtonian pseudoplastic behaviour, while the presence of yield stress (τ_0) for most of the samples at 25 °C highlighted a plastic behaviour, in agreement with the literature (Ahmed & Ramaswamy, 2006; Alonso, Larrode, & Zapico, 1995; E. Alvarez, Cancela, & Maceiras, 2007; M. Alvarez, Canet, & Herranz, 2017; Krokida, Maroulis, & Saravacos, 2001)

The rheological behaviour was affected by temperature with a decrease in shear stress at 40 °C in all samples. Commercial F food exhibited the lowest shear stress values over all the shear rate range, NWP *formulae* had the highest ones, while M food and other "Pappa di Parma" meals showed an intermediate rheological behaviour (Fig. 1) at both the temperatures analyzed.

The Herschel–Bulkley model was used to describe the flow behaviour of the meals and the R^2, τ_0, n and K parameters obtained have been summarized in Table 4. Yield stress (τ_0) represents a minimum shear

Table 3
Nutritive values of "Pappa di Parma" *formulae* per 100 g meal. In brackets, the % covered of the recommended nutrient intakes (WHO and FAO, 2004) or of the adequate intakes (EFSA, 2017), referred to a daily serving size accounting for 2000 kcal. WMP: water-milk power formula; WCB: water-corn-bean flours; WSB: water-sesame-bean flour formula; NWP: no water-peanuts flour formula; NWS: no water-soya flour formula; NWF: no water-fish flour formula. Zero means no ingredient providing the nutrient.

Component (100 g)	WMP	WCB	WSB	NWP	NWS	NWF
Energy (kcal)	467.89	406.00	413.31	518.40	539.51	519.60
Proteins (% total energy)	10.80	12.13	11.93	11.13	9.96	11.66
Lipids (% total energy)	58.48	52.59	53.60	61.70	62.97	59.03
Sodium (mg)	101.61	7.17	4.33	4.07	5.77	41.63
Potassium (mg)	527.89 (+105)	303.39 (+36)	304.00 (+34)	270.76 (−5)	751.69 (+153)	303.80 (+6)
Calcium (mg)	247.82 (+77)	116.00 (−5)	211.20 (+70)	316.96 (+104)	225.21 (+39)	371.65 (+138)
Phosphorus (mg)	359.09 (+249)	216.28 (+142)	239.87 (+164)	219.39 (+92)	262.10 (+121)	346.65 (+203)
Magnesium (mg)	107.64 (+505)	59.51 (+286)	73.78 (+370)	115.00 (+484)	164.31 (+701)	109.85 (+456)
Iron (mg)	2.12 (+44)	9.62 (+652)	10.42 (+700)	7.22 (+342)	5.12 (+201)	4.00 (+144)
Zinc (mg)	2.76 (+146)	0.75 (−23)	1.32 (+33)	2.33 (+87)	2.21 (+70)	2.21 (+77)
Copper (mg)	0.36 (+54)	0.19 (−8)	0.59 (+184)	1.35 (+422)	0.83 (+206)	0.75 (+187)
Vitamin A (μg RAE)	551.18 (+424)	428.21 (+369)	336.40 (+262)	444.60 (+281)	672.31 (+454)	625.00 (+435)
Vitamin C (mg)	14.27 (+103)	9.91 (+63)	11.56 (+86)	17.87 (+130)	20.62 (+155)	15.21 (+95)
Vitamin D (μg)	0.00	0.00	0.00	0.00	0.00	0.25 (−94)
α-tocopherol (mg)	3.10 (+165)	3.96 (+290)	3.04 (+194)	4.41 (+240)	5.34 (+296)	5.71 (+340)
Thiamin (mg)	0.26 (+83)	0.19 (+57)	0.23 (+88)	0.26 (+69)	0.14 (−13)	0.36 (+133)
Riboflavin (mg)	0.41 (+193)	0.20 (+68)	0.18 (+49)	0.17 (+10)	0.34 (+109)	0.14 (−9)
Niacin (mg)	1.63 (−13)	2.06 (+27)	2.03 (+23)	8.18 (+295)	2.39 (+11)	3.00 (+44)
Pantothenic acid (mg)	1.02 (+45)	0.40 (−34)	0.41 (−33)	0.06 (−92)	0.06 (−93)	0.05 (−94)
Vitamin B6 (mg)	0.28 (+98)	0.17 (+38)	0.24 (+90)	0.26 (+66)	0.24 (+51)	0.25 (+59)
Folate (μg)	45.57 (−3)	30.49 (−25)	36.22 (−12)	31.80 (−39)	77.49 (+44)	41.68 (−20)
Cobalamin (μg)	0.68 (+143)	0.00	0.00	0.00	0.00	1.50 (+381)

stress to be exceeded before flow beginning and structure breakdown (Bourne, 2002; Guerrero & Alzamora, 1998) and is caused by strong interactions between the colloidal particles or the formation of links between the long-chain molecules which caused reticular structures to break (Alonso, Larrode, & Zapico, 1995). Taking in mind this, it is easy to understand the importance of this rheological parameter on the product's palatability. The F food exhibited plastic behaviour at both temperatures ($\tau_0 \approx 6$ Pa), while the M food showed no resistance to flow. Except for the WMP sample, all the *formulae* showed plastic behaviour with a τ_0 lower than 40 Pa (ranging between 4.5 and 39 Pa and 3–26 Pa at 25 °C and 40 °C, respectively). Overall, the parameter decreased with the temperature increase. Our τ_0 values were comparable to those found in the literature, where authors reported a wide range of variability depending on the baby food formulation and the temperatures of analysis [between 8 and 29 Pa for fruit and vegetable-based infant foods analyzed at 25 °C (Alonso, Larrode, & Zapico, 1995); up to 58 Pa for blueberry-puree based preparations analyzed in a temperature range of 27–93 °C (Kechinski et al., 2011); between 0.20 and 67 Pa for meat-based strained baby foods analyzed in a temperature range of 5–80 °C (Ahmed & Ramaswamy, 2007); between 0.54 and 1.76 Pa for sweet potato puree infant foods analyzed in a temperature range of 5–80 °C (Ahmed & Ramaswamy, 2006); between 2 and 14 Pa for vegetable – meat infant purees analyzed between 5 and 65 °C (Alvarez, Canet, & Herranz, 2017)].

The flow behaviour index (*n*) is a dimensionless number which indicates closeness to Newtonian flow behaviour (Bourne, 2002). Commercial and "Pappa di Parma" samples reported an *n* value ranging from 0.2 to 0.6 at any temperature, which is typical for products with pseudoplastic behaviour ($n < 1$), such as the infant foods previously investigated (Ahmed & Ramaswamy, 2006; Alvarez, Cancela, & Maceiras, 2007; Glicerina, Balestra, Pinnavaia, Dalla Rosa, & Romani, 2013; Krokida, Maroulis, & Saravacos, 2001). Moreover, the n value of almost all the meals was not significantly temperature - dependent.

With regard to the consistency index (*K*, Table 5), F food samples showed the lowest *K* at both the temperatures considered (< 20 Pa•s^n), while M food ones showed high *K* index values (≈70 Pa•s^n and ≈60 Pa•s^n at 25 °C and 40 °C, respectively). Having an opposite consistency, the F and M foods were assumed as reference limits in the "Pappa di Parma" *formulae K* evaluation. Although large differences in the magnitudes of the *K* values were reported for the "Pappa di Parma" *formulae*, which ranged between ≈25 Pa•s^n and ≈77 Pa•s^n at 25 °C and between ≈20 Pa•s^n and ≈60 Pa•s^n at 40 °C, all the meals had intermediate behaviour among two commercial reference foods, thus demonstrating their rheological suitability for infant consumption.

K decreased systematically with an increase in temperature, as expected and in agreement with previous observations on baby foods (Ahmed & Ramaswamy, 2006; Ahmed & Ramaswamy, 2007; Alvarez et al., 2007). Rheological properties can be influenced by other factors such as the amount of solid vegetable fats and/or saturated fatty acids provided by the presence of ASFs (Glicerina, Balestra, Pinnavaia, Dalla Rosa, & Romani, 2013), the starch content derived from the use of pulse, cereal and tuber flours (Table 2) (Ahmed & Ramaswamy, 2006; Alonso, Larrode, & Zapico, 1995), the protein content and the degree of protein hydration (which are responsible for pseudo-gel structure formation in foods), the amount of water with its plasticizing and diluting effect. Moreover, the content and average size of the particles in the dispersed phase related to meals processing may have had an impact on rheological properties of different *formulae* (Alvarez et al., 2017).

3.3. Physicochemical properties

The physicochemical properties of the *water formulae* (t0) and the *no-water formulae* (t0 and t90) are reported in Table 5.

As expected, the moisture content of the *water formulae* (≈29.4%, ≈58.6% and ≈43.5% for WMP, WCB and WSB, respectively) at t0 was significantly higher ($P \leq 0.05$) than that of the *no-water formulae* (≈1.4%, ≈3% and ≈2.6% for NWP, NWS and NWF, respectively), due to the addition of water when preparing the meals (rehydration of beans, corn and manioc flours). Instead, the NWP, NWS and NWF *formulae* were all prepared without the use of water.

In addition, after 90 days storage (t90), the MC (%) of the *no-water formulae* had slightly decrease contingent on the storage conditions (temperature, light, air exposure), especially when stored in a non-airtight bag at 40 °C and exposed to light (≈0.8%, ≈1.58%, ≈1.90% for NWP, NWS, NWF, respectively).

Water activity is one of the most critical factors in determining the quality and safety of foods, since it strongly impacts such reactions as enzymatic or non-enzymatic browning, lipid oxidation or microbial growth. As it is well known, the two critical a_w reference values at room temperature are 0.6 for limiting the growth of any microorganisms and 0.86 for the growth of pathogenic bacteria (Ross, 2007). As expected, the water activity (a_w) of all the *water formulae* was higher than 0.90 (0.90, 0.99, 0.97 for WMP, WCB, WSB, respectively), while the *no-water formulae* showed a_w values lower than 0.45 (0.41, 0.45, 0.39 for NWP,

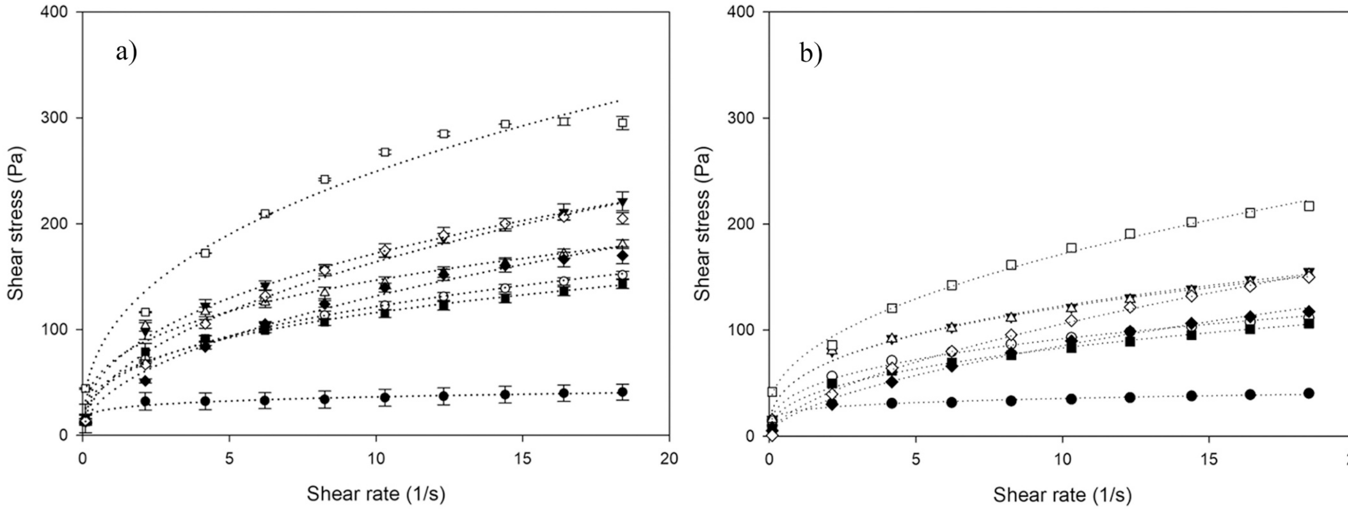

Fig. 1. Flow curves measured by increasing shear rate at 25 °C (a) and 40 °C (b) fitted with the Herschel-Bulkley model. ● F food; ○ M food; ▼ WMP; △ WCB; ■ WSB; □ NWP; ◆ NWS; ◇ NWF; ····· Herschel-Bulkley model.

Table 4
Herschel–Bulkley model parameters of "Pappa di Parma" *formulae* and industrial infant foods. For each sample, different lowercase letters indicate a significant difference (paired sample *t*-Test, p ≤ 0.05) between temperatures for the same product. Different capital letters indicate significant differences (one-way ANOVA with Duncan's *post-hoc* test, *p* ≤ 0.05) between different samples at the same temperature. WMP: water-milk powder formula; WCB: water- corn-bean flours; WSB: water-sesame-bean flour formula; NWP: no water-peanuts flour formula; NWS: no water-soya flour formula; NWF: no water-fish flour formula.

Sample	T (°C)	R^2	τ_0 (Pa)	K (Pa•s^n)	n
F food	25	0.99	5.75 ± 0.17 aC	18.20 ± 6.87 aE	0.24 ± 0.07 aE
	40	0.98	6.57 ± 5.96 aC	16.93 ± 9.25 aD	0.23 ± 0.04 aD
M food	25	0.96	0.00 ± 0.00 aC	73.14 ± 2.53 aA	0.24 ± 0.01 aE
	40	0.92	0.00 ± 0.00 aC	59.71 ± 0.11 bA	0.20 ± 0.01 bD
WMP	25	1.00	0.00 ± 0.00 aC	74.35 ± 1.20 aA	0.37 ± 0.01 aD
	40	1.00	0.00 ± 0.00 aC	58.04 ± 3.62 bA	0.34 ± 0.02 aC
WCB	25	1.00	39.00 ± 13.10 aA	26.40 ± 4.33 bD	0.58 ± 0.03 aA
	40	1.00	14.95 ± 3.63 bC	56.72 ± 3.94 aA	0.34 ± 0.02 bC
WSB	25	1.00	24.03 ± 0.07 aB	26.61 ± 0.65 aD	0.52 ± 0.01 aB
	40	0.99	14.95 ± 2.57 bB	19.31 ± 2.38 bCD	0.53 ± 0.02 aB
NWP	25	0.97	28.70 ± 0.70 aB	77.01 ± 2.46 aA	0.44 ± 0.01 aC
	40	1.00	25.99 ± 9.28 aA	44.15 ± 8.75 bB	0.50 ± 0.05 aB
NWS	25	0.99	6.29 ± 3.66 aC	36.56 ± 2.48 aC	0.52 ± 0.02 aB
	40	0.99	3.38 ± 4.77 aC	20.19 ± 2.14 bCD	0.59 ± 0.04 aA
NWF	25	0.98	4.59 ± 1.61 aC	50.57 ± 2.41 aB	0.48 ± 0.01 bBC
	40	1.00	0.00 ± 0.00 bC	26.62 ± 1.65 bC	0.58 ± 0.02 aA

NWS, NWF), which significantly decreased ($P \leq 0.05$) after 90 days (t90) in all the storage conditions tested (Table 5).

The pH varied significantly ($P \leq 0.05$) among the samples resulting ≈ 6 for *water formulae* and ≈ 4 *for no-water formulae*. The *no-water formulae* acid pH value may have been influenced by the use of acidic baobab fruit pulp powder as an ingredient. At t90, the pH decreased in all the storage conditions for NWP and NWS, while a slight increase was recorded for NWF (Table 5).

As expected, the physico-chemical parameters recorded for *water formulae* were unable to ensure the shelf-stability of the products not immediately consumed. Furthermore, the lack of low temperature preservation technologies in low-income countries requires the consumption of meals immediately after preparation. In contrast, NWP, NWS and NWF meals included no water and the a_w and pH values can guarantee their stability towards microbial growth almost during the storage period tested.

Colour parameters (L^*, a^* and b^*) of the six "Pappa di Parma" meals measured at t0 and t90 are presented in Table 5. The significantly higher L^* values recorded for the *water formulae* compared to those of the *no-water formulae*, were related to the diluting effect of the water which led to a less dense, light-coloured and therefore bright finished product. *No-water formulae* recorded significantly lower L^* and b^* values than *water formulae*, indicating a loss of colour lightness and of yellow hue, since the redness of the palm oil would have affected their colour more given the minimal moisture content. Overall, yellow – red hues varied according to the formulation, type and amount of the ingredients. WCB recorded the highest L^* (≈ 65.6), the lowest a^* (≈ 10.6) and highest b^* values (≈50.2) related to its high MC (%), while the dark hues shown by the highest a^* measured for NWP (≈16.5) may be related to the reddish and greyish notes provided by palm oil and peanut flour. NWF was the sample with the lowest L^* (≈11.6) and b^* (≈30.2) values, since the addition of fish flour caused an evident browning of the finished product. After 90 days' storage, colour parameters significantly changed in NWP, NWS and NWF, and ΔE values were calculated to evaluate whether these differences were perceptible to the human eye (the higher the value, the higher the perceived differences between t90 and t0 samples) (Limbo & Piergiovanni, 2006). ΔE values between 3.0 and 4.4 were found for NWP samples, leading to a perceptible colour difference from t0, while ΔE between 7.3 and 9.9 calculated for NWS denoted a strong difference in comparison to t0 for NWS samples. The colour of the NWF sample was more stable compared to the other samples after 90 days, showing a ΔE lower than 3 (noticeable difference) in all storage conditions.

The changes of colour might be given by the outset of physico-chemical reactions attributable to factors related to the food composition (sugars, enzymes, metal ions, etc.) or to storage conditions (temperature, light, oxygen, etc.). Moreover, a possible slight phase separation between the oil and solid fractions may have accelerated these reactions, thus contributing to the products' colour change.

3.4. Lipid oxidation

Peroxide value (PV) is an estimation of the overall oxidation status for lipids and lipid-containing foods, especially in the primary phase of oxidation (Gray, 1978). It is a major parameter to evaluate the quality of lipids (Eldin, 2010) and its kinetic is often analyzed to determine the

Table 5
"Pappa di Parma" physico-chemical characteristics measured at day 0 (t0) and 90 (t90) after production in different storage conditions. Values are expressed as means ± SD. WMP, WCB and WSB *formulae* require to be consumed immediately after preparation, thus data were acquired only at t0.
For MC. a_w. pH. L*. a* and b* at t0: different lowercase letters in each row indicate significant differences (one-way ANOVA with Duncan's post-hoc test $p \leq 0.05$) between samples at the same storage time. For each sample, different capital letters indicate significant differences (one-way ANOVA with Duncan's post-hoc test $p \leq 0.05$) between t0 and all the values recorded at t90 in different storage conditions.

		WMP	WCB	WSB	NWP			NWS		NWF			
	Day				*25 °C. vacuum. Dark stored*	*25 °C. no vacuum. Light stored*	*40 °C. no vacuum. Light stored*	*25 °C. vacuum. Dark stored*	*25 °C. no vacuum. Light stored*	*40 °C. no vacuum. Light stored*	*25 °C. vacuum. Dark stored*	*25 °C. no vacuum. Light stored*	*40 °C. no vacuum. Light stored*
MC (%)	*0*	29.37 ± 0.95c	58.56 ± 0.3a	43.49 ± 0.14b		1.38 ± 0.12eA			2.96 ± 0.07dA			2.58 ± 0.08dA	
	90	/	/	/	1.31 ± 0.09A	1.27 ± 0.02A	0.77 ± 0.08B	2.72 ± 0.00B	2.60 ± 0.06B	1.58 ± 0.02C	2.51 ± 0.01A	2.32 ± 0.09B	1.94 ± 0.06C
a_w	*0*	0.90 ± 0.00c	0.99 ± 0.00a	0.97 ± 0.00b		0.41 ± 0.01eA			0.45 ± 0.00dA			0.39 ± 0.02eAB	
	90	/	/	/	0.38 ± 0.00A	0.35 ± 0.01B	0.30 ± 0.00C	0.38 ± 0.00B	0.36 ± 0.00C	0.32 ± 0.00D	0.41 ± 0.01A	0.36 ± 0.01B	0.31 ± 0.01C
pH	*0*	5.78 ± 0.08c	6.29 ± 0.1a	6.13 ± 0.10b		4.23 ± 0.06dA		4.14 ± 0.02eA				3.63 ± 0.07fC	
	90	/	/	/	3.99 ± 0.02bB	3.92 ± 0.04B	3.93 ± 0.04B	3.83 ± 0.05B	3.76 ± 0.03BC	3.78 ± 0.03B	3.75 ± 0.02A	3.71 ± 0.00AB	3.74 ± 0.04AB
L*	*0*	56.2 ± 0.4c	65.64 ± 0.65a	58.65 ± 1.5b		51.09 ± 0.38 dB			51.39 ± 0.37dC			44.77 ± 1.05eB	
	90	/	/	/	51.71 ± 0.76A	50.94 ± 0.63B	50.72 ± 0.55B	57.35 ± 0.74A	56.26 ± 0.53B	57.02 ± 0.42B	45.55 ± 0.83A	45.46 ± 0.59A	45.83 ± 0.85A
a*	*0*	13.51 ± 0.48c	10.59 ± 0.35f	12.36 ± 0.91d		16.51 ± 0.41aBC			14.71 ± 0.16bD			11.6 ± 0.57eA	
	90	/	/	/	16.78 ± 0.58AB	16.89 ± 0.32A	16.38 ± 0.19C	17.60 ± 0.81A	17.1 ± 0.35B	15.7 ± 0.40C	10.94 ± 0.43B	10.00 ± 0.34C	9.71 ± 0.32C
b*	*0*	48.08 ± 1.73b	50.2 ± 1.91a	47.25 ± 2.6b		39.27 ± 1.04dA			42.02 ± 0.84cD			30.18 ± 1.8eB	
	90	/	/	/	34.92 ± 1.92C	35.72 ± 1.13BC	36.26 ± 0.7B	49.36 ± 1.60A	48.06 ± 0.98B	46.48 ± 0.90C	31.23 ± 1.41A	28.46 ± 0.80C	28.73 ± 1.01C
ΔE	*0*	/	/	/		/			/			/	
	90	/	/	/	4.4	3.6	3.0	9.9	8.1	7.3	1.5	2.4	2.6
PV (mEQ/kg oil)	*0*	/	/	/	0.98 ± 0.03b	0.98 ± 0.03e	0.98 ± 0.03d	0.98 ± 0.02c	0.98 ± 0.02c	0.98 ± 0.02c	0.98 ± 0.00de	0.98 ± 0.00d	0.98 ± 0.00d
	2	/	/	/	0.96 ± 0.00b	2.89 ± 0.14c	2.48 ± 0.38bcd	2.32 ± 0.49abc	4.07 ± 0.20b	2.74 ± 0.16a	2.33 ± 0.42bc	0.97 ± 0.00d	3.76 ± 0.07a
	7	/	/	/	2.78 ± 0.05a	5.42 ± 0.81a	2.86 ± 1.02bc	3.14 ± 0.58ab	8.42 ± 2.24a	2.72 ± 0.83a	2.85 ± 0.05b	8.72 ± 0.14a	3.36 ± 0.48ab
	15	/	/	/	2.41 ± 0.47a	4.18 ± 0.89b	1.85 ± 0.04 cd	3.30 ± 1.53a	3.59 ± 0.99b	2.31 ± 0.51ab	4.81 ± 0.99a	3.37 ± 0.60b	3.19 ± 0.49b
	50	/	/	/	2.28 ± 0.57a	1.33 ± 0.54de	4.04 ± 1.32ab	2.02 ± 0.36abc	2.46 ± 0.76bc	2.08 ± 0.50ab	1.67 ± 0.08 cd	2.59 ± 0.21c	1.70 ± 0.06c
	90	/	/	/	2.71 ± 0.22a	1.84 ± 0.03d	4.62 ± 1.22a	1.84 ± 0.01bc	0.85 ± 0.01c	1.69 ± 0.00bc	0.38 ± 0.38e	2.71 ± 0.26c	1.67 ± 0.14c

For peroxide value (PV): different lowercase letters in each column indicate significant differences (one-way ANOVA with Duncan's *post-hoc* test, $p \leq 0.05$) between different storage times.

product's shelf life (Barden & Decker, 2016).

The peroxide value results (PV) for the oil fraction extracted from *no-water formulae* at t0, t2, t7, t15, t50 and t90 over the three different storage conditions are shown in Table 5.

At t0, the peroxide value is comparable between the different samples (≈0.98 mEq/kg oil); during the three months of analysis, the lipid oxidation followed variable kinetics contingent on the type of sample and the storage conditions.

For the NWP sample, a slight increase in the PV up to t7 was observed when stored at 25 °C (≈2.8 mEq/kg oil and ≈5.4 mEq/kg oil under vacuum dark and light, respectively), while a slight progressive increase occurred up to t90 when stored at 40 °C (≈4.6 mEq/kg oil).

The NWS and NWF samples showed similar oxidation kinetics under the same storage conditions, characterized by a slight significant increase followed by a progressive decrease. For both samples, the most protective storage conditions (vacuum, darkness, and 25 °C) delayed the PV peak to t15, a peak which was anticipated to t7 and t2 in the absence of a vacuum, the presence of light, and the highest storage temperature (Table 5).

In general, the slight fluctuation in the number of peroxides was never enough to exceed a value of 10 mEq/kg, thus remaining well below the threshold of unacceptability and showing good resistance to the oxidative process up to 90 days after production as a minimum.

The results suggested that the various meals have a reasonably long shelf-life and it is conceivable that deterioration of the product's quality concerning lipid oxidation only began after the observation period. These results can be justified by the water activity of the meals (≈0.4) and possibly to the plausible high presence of antioxidants provided by ingredients such as seeds and oilseeds, etc., that may have contributed to the oxidative stability of the meals.

3.5. Economic sustainability

An investigation of local availability and affordability of ingredients to reproduce the "Pappa di Parma" in local context was carried out at local markets closest to the city of Sumbawanga (Rukwa region, Tanzania). The investigation revealed the unavailability of high-protein peanut flour and fish flour, used in NWP and WNF meals, respectively, which, as a result, were not possible to be replicated in Tanzania. Despite ease in finding fresh fish at the markets thanks to the proximity to Lake Tanganyika, the lack of drying technologies suitable to obtain a safe product stable enough for human health prevented reproduction of NWF food in the Tanzanian context. These hindrances were highlighted only when "Pappa di Parma" was implemented at a local level. This suggests that to guarantee the feasibility of any type of nutrition interventions in an African country, a strong partnership driven by local context is mandatory. Even so, NWF "Pappa", together with NWP, remain valid alternatives to supplement the diet of malnourished children in circumstances where there is availability of fishmeal or hyper-protein peanut flour.

All other ingredients were found with greater or lesser ease depending on the size of the market and the stock available. Ingredients such as beans, oilseeds and nuts, palm oil and starchy foods were the easiest to find since they represent the main energy sources of the local population's diet.

The cost of the "Pappa di Parma" *formulae* was assessed taking into account the price of the raw materials and the quantities necessary for the production of a daily portion (Table 2). The cost calculated for a 100 g meal was $0.37 for WMP, $0.10 for WCB and WSB, $0.19 for NWS. The higher price of the WMP formula is due to the presence of the powdered milk which, being imported, has a high price even though it is readily available at local markets. By and large, the "Pappa di Parma" was considered economically sustainable, in light of the disposable income of Tanzanian families (World Bank Group, 2019).

3.6. Satisfaction survey

The sensory quality of food contributes much to the emotional wellbeing of consumers and drives acceptability more than nutritional quality. Therefore, making sure that food products are culturally appropriate, acceptable and preferred is fundamental in nutrition intervention strategies (Rakotosamimanana & De Kock, 2020).

Overall, the liking assessment revealed a high appreciation of all the preparations: 94% of children liked the WCB, 96% the WSB, 97% the WMP and 98% the NWS formula, with no association found between the "Pappa di Parma" *formulae* and liking. Similarly, there was not an association between the Pappa di Parma" *formulae* and willingness to prepare them. The majority of the mothers (97% in the case of the WMP, 99% for NWS and 100% for WCB and WSB *formulae*) declared their willingness to prepare the "Pappa di Parma" by themselves for their child. When interviewed about their willingness to buy a ready-to-eat "Pappa di Parma" in a context of collective production, such as a school or dispensary, the majority of the mothers were in favour of buying WSB (96%), NWS (99%), and WCB (100%), while only 79% were in favour of buying the WMP formula, almost certainly because of the highest cost, showing an association between the Pappa di Parma" *formulae* and willingness to buy them ($p < 0.001$). In addition, irrespective to the preparation, no associations were observed between liking and sex of children and between liking and both willingness to prepare and willingness to buy the "Pappa di Parma". These results suggested that "Pappa di Parma" meals made with locally available ingredients are sustainable and culturally accepted alternatives which could be potentially effective against MAM.

4. Conclusions, recommendations and future perspectives

Six formulations of "Pappa di Parma" targeted to children aged 6 to 60 months affected by MAM were developed. In order to potentially deliver sustainable *formulae*, simple technologies and locally available ingredients (Rukwa region, Tanzania) were used. On the basis of the nutritional data, a daily portion of "Pappa" is potentially able to meet the energy and macronutrients requirements for malnourished children (Ashworth et al., 2003) and to provide a dose which is well above the recommended values for a healthy child for most micronutrients (EFSA, 2017; WHO and FAO, 2004). The implementation of the "Pappa di Parma" in local context confirmed that meals were found culturally accepted and economically sustainable, because of two key elements. Firstly, they were composed by locally available and economically accessible ingredients which are not aliened to eating habits and culinary traditions. Secondly, families (especially children and mothers) were involved in an education program. Furthermore, data collected from rheological, physico-chemical and lipid oxidation characterization proved the suitability and stability of *no-water formulae* in all storage conditions for three months. All these features are certainly the strengths and the novelty of this study. However, consistent limitations that have to be analyzed to hypothesize future perspective, were found.

Considering all *formulae* developed, from nutritional point of view, some limitations on the amount of certain micronutrients (e.g. vitamin B12) were ascertained. To address them, the integration of the home diet with fruits, vegetables, ASFs, and fortified ingredients, when possible, can be an effective solution to improve the nutritional intake of malnourished children in a domestic context using these preparations.

From safety and quality point of view, different issues can be considered based on the different type of "Pappa di Parma" *formulae* developed, that is *water* or *no-water formulae*. The *water formulae* require to be consumed immediately after preparation. Thus, their implementation is recommended in the framework of a structured educational intervention on the correct hygienic practices for food handling, transformation and consumption. Nevertheless, further researches are needed to verify micronutrient stability, especially when a pre-treatment of the ingredients is required.

For *no-water formulae,* the discussion should be addressed to the internationally accepted operating procedures [the Recommended International Code of Hygienic Practice for Foods for Infants and Children of the Codex Alimentarius (Codex Alimentarius Commission, 1981), the HACCP and the nationally adopted Bureau of Standards which regulate the production of food (Manary, 2006; Santini et al., 2013)] that specify a series of reference criteria (i.e. technological, microbiological and chemical) concerning ingredients and finished products that a RUTF is subjected to. Standard regulations established that RUTFs must appear as a smooth and uniform emulsion with small particle size (< 200 μm) to guarantee no grittiness and lumps and to avoid oil separation during the storage period (Manary, 2006; Santini et al., 2013). Moreover, despite the intrinsically microbiological shelf-stability of the products, the identification and limitation of potential microbial hazards must be considered (with the highest priority for *Salmonella*, *L. monocytogenes*, C. b*otulinum*) especially when ingredients and finished product are stored and handled under inappropriate conditions (Caron, 2012). The food should not contain any poisonous or deleterious substances, including antinutritional factors, heavy metals pesticides or mycotoxins in amounts that may represent a hazard to health (e.g. aflatoxin level 5 ppb maximum). The mycotoxins risk is especially connected to the non-safe conditions where locally foodstuffs are stored (WHO, UNICEF, WFP and UN System Standing Committee on Nutrition, 2007). Thus, further investigations are needed to study and verify the conformity of our formulations to the RUTFs' production requirements, and to implement them in local production realities able to execute a quality control system on the ingredients, production lines and final products. Moreover, an appropriately powered clinical trial is required to assess the effectiveness of "Pappa di Parma" meals to recover 6–60 months children from MAM, while an educational intervention program could be effective to scale up the approach to all families transferring knowledge and skills among mothers.

Concluding, the "Pappa di Parma" *formulae,* composed by local available ingredients, and the integrated and multidisciplinary approach used represent a valid and solid starting point to further study the possibility to find economic and environmentally sustainable effective alternatives to RUTFs.

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Author statement

All persons who meet authorship criteria are listed as authors, and all authors certify that they have participated sufficiently in the work to take public responsibility for the content, including participation in the concept, design, analysis, writing, or revision of the manuscript. Furthermore, each author certifies that this material or similar material has not been and will not be submitted to or published in any other publication before its appearance in the *Hong Kong Journal of Occupational Therapy*.

Authorship contributions

Please indicate the specific contributions made by each author (list the authors' initials followed by their surnames, e.g., Y.L. Cheung). The name of each author must appear at least once in each of the three categories below.

Declaration of Competing Interest

The authors declare that there are no conflicts of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ifset.2020.102534.

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