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New food, new technology: innovative spreadable cream with strawberry syrup

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Abstract
A strawberry spreadable cream was developed, valorizing regional raw materials, contributing to food waste reduction and agri-food ecosystem sustainability. Spreadable creams are water-in-oil emulsions whose lipid phase normally contains a blend of vegetable oils, natural colourants, stabilizers, emulsifiers, flavourings, antioxidants, lecithin, and fat-soluble vitamins. The aqueous phase normally contains skim milk proteins and small quantities of other ingredients, such as salt, preservatives, thickeners, and water-soluble vitamins. The methodology involved the experimental technological development articulated with microbiological, proximal, physicochemical, and sensorial analysis. This new product revealed nutritional advantages over similar products already on the market. The final prototype was subjected to food pairing and food design with incremental acceptance according to gastronomic use, in addition to its direct use as a spreadable cream. This work was part of the project Agrio et Emulsio—new products development (POCI-01-0145-FEDER-023583), whose main objective was the formulation and design of innovative food emulsions based on processed raw materials, with potential application in certain markets such as gourmet, diet, and vegan.

Keywords Water-in-oil food emulsion · Strawberry syrup · Innovative spreadable cream · Sustainable agri-food system

Introduction

To pursue a healthy lifestyle, consumers are looking for new, diversified and more convenient products. The development of new products to meet these consumers' expectations must be done to achieve sustainable development goals [1,2]. With this purpose, innovative food emulsions, as spreadable creams, could be developed, valuing secondary agricultural raw materials with potential application in food industry and thus reducing waste. Based on sustainable methodologies, an innovative spreadable cream, with different additions, was developed for markets in general, but also suitable for diet and vegan consumers [3].

An emulsion is a multiphase thermodynamically unstable system, consisting of two immiscible phases, an aqueous and a lipidic, where one of the phases is dispersed in the other (continuous phase) in the form of spherical droplets. The mean diameter of the droplets in emulsified food products typically falls somewhere in the range of 0.1 to 100 µm. Emulsions can be conveniently classified according to the relative spatial distribution of the different phases [4]. The lipidic phase consists of hydrophobic substances: a blend

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of vegetable oils and/or oils and animal fats, saturated and unsaturated free fatty acids, sterols, phytosterols, several emulsifiers like mono-acyl glycerol (MAG), di-acyl glycerol (DAG), and tri-acyl glycerol (TAG), natural colourants, stabilizers, flavourings, antioxidants, phospholipid such as lecithin and liposoluble vitamins. The aqueous phase consists of hydrophilic substances: polysaccharides, alkalis, acidity regulator, salt, water-soluble vitamins, preservatives, thickeners, and milk proteins [5,6]. Emulsions can basically be of two types: oil-in-water (o/w), wherein the dispersed phase is lipidic; and the continuous phase is aqueous, forming a normal micelle at the interface and water-in-oil (w/o) wherein the dispersed phase is aqueous, and the continuous phase is lipidic, forming an inverse micelle at the interface [7,8]. The preparation of emulsions that are kinetically stable over time that is of practical use to the food industry (e.g. a few days, weeks, months, or years) requires the incorporation of substances known as stabilizers. Stabilizers can be classified according to their mode of operation as either "emulsifiers" or "texture modifiers". An emulsifier is a surface-active substance that adsorbs to the surface of emulsion droplets to form a protective coating that prevents the droplets from aggregating with one another, e.g. certain proteins, polysaccharides, phospholipids, small molecule surfactants, and solid particles [4,5]. An emulsifier also reduces the interfacial tension and therefore facilitates the disruption of emulsion droplets during homogenization, which aids in the formation of emulsions containing smaller droplets [9,10]. The membrane that supports the droplets stabilizes the system and is located at the interface, where there is competition for the adsorption of various emulsifying components, as they are substances with affinity for both phases [9–12]. A vegetable spreadable cream is essentially a water-in-oil (w/o) emulsion, with solid fat crystals forming a three-dimensional network. The network of fat crystals surrounds the droplets of the dispersed aqueous phase and is embedded in the continuous lipidic phase, forming a membrane at the interface [13,14]. So, the rheological behaviour of a spreadable cream mainly depends on the crystalline form of the fatty acids (polymorphic form α, β or β') and the processing techniques used [15–17]. The polymorphic form haveGreek letters, namely, a is α, b is β and b' is β'. The lipidic content, continuous and dispersed phases between the aggregated crystalline network, together with the solid fraction are, according to Walstra [9] and McClements [4,5], responsible for the viscoelastic behaviour, denoting solid-like behaviour.

The innovative nature of these spreads corresponds to the fact that other ingredients have been incorporated within the product, such as strawberry syrup, maintaining the rheological characteristics of a normal spreadable cream, i.e. its spreadability [18,19]. As new products, it is necessary to ensure not only the regulatory requirements for food safety, but also the quality perceived and demanded by consumers [20–22].

Spreadable creams are known to become unstable at temperatures above 8 °C. Since they have lipidic crystals in their structure, if the product is subjected to heat treatment, the lipidic crystals melt, and the network is destroyed destabilizing the emulsion, resulting in phase separation [4,5,9,14–16].

Materials and methods

Technological development

The methodology [3] used for food emulsions prototyping process development included technological assays articulated with sensorial and analytical evaluation.

Technological process strawberry syrup development

The main constituents of syrup were strawberry, sweetener (fructose), acidity regulator (lemon juice), and a thickener (pectin). The strawberry syrup was produced at a temperature about 90 °C.

There were developed four strawberry syrup pre-prototypes A1, A2, A3 and A4 with different formulations. For each of them, the total soluble solids content (TSS in ºBrix), total acidity (TA), and pH were determined. These results, of pre-prototypes, are not presented here.

Technological process of production of spreadable creams

In emulsion production, the aqueous phase was prepared with a mixture of a beverage of vegetable origin acquired in the market and natural lemon juice (as an acidity regulator). The lipidic phase consisted of a blend of sunflower oil, coconut fat (solid), and soy lecithin (emulsifier).

All this procedure was carried out at low temperature, always bearing in mind the good manufacturing practices in terms of hygiene and food safety. The process was performed at laboratory scale in five steps:

First: melting of coconut fat (solid) and addition of vegetable oil and emulsifier, promoting agitation at a temperature about 0 °C approximately; fat crystal creation—crystallization (chilling).

Second: addition of an aqueous phase mix, with continuous agitation, at a temperature about 0 °C, forming a w/o emulsion.

Third: addition of strawberry syrup, with continuous agitation, at a temperature of about 0 °C.

Fourth: formation of spreadable cream.

Fifth: filling and storage at a temperature of about 5 °C.

At the beginning, five prototypes were developed in series No. 1, with the following conditions: different formulations of strawberry fructose syrups; different beverages of vegetable origin for aqueous phase and different formulations of spreadable creams. The prototype codes of series No. 1 were designated by: A12, A13, A24, A33 and A44, where the first digit corresponds to the syrup formulation and the second digit the emulsion formulation used. Physicochemical analyses were performed such as determination of pH, total acidity (TA), and total soluble solid content (TSS in ºBrix). Beyond analytical characterization, these prototypes were also evaluated by an untrained taster's panel. According to sensorial results and panellists' suggestions, the added syrup and w/o emulsion were reformulated, pursuing technological development to formulate three new prototypes for series No. 2: A55, A65, and A75. For these new prototypes, the same physicochemical analyses were carried out and samples were also subjected to sensorial evaluation. Based on the results of the taster's panel, a final prototype, A55, was selected. Microbiological, physicochemical, and proximal analyses were carried out. This final prototype was subjected to food pairing and food design, as described elsewhere [23,24].

Sensorial evaluation

The sensorial tests were hedonic, performed with an untrained taster's panel and the parameters evaluated followed Richardson-Harman et al.'s [25] recommendations. The evaluated attributes were appearance, associated with the vision sense (colour and brightness), texture associated with mechanoreceptor senses (consistency and spreadability), aroma associated with the olfactory sense (strawberry, coconut, lemon), taste associated with the palate sense (sweetness, acid, fat, strawberry, and coconut), and overall assessment. For this evaluation, depending on test sessions, the number of panel members varied between 25 and 35. For treatment of the results and considering the scores assigned by each panellist in the tasting sheet, the weighted average for each attribute was computed and radar and circular (overall assessment) charts were built.

Microbiological analyses

Microbiological evaluation followed the recommendations and rules for microbiological analyses of food, according to International Organization for Standardization ISO 7218:2007 [26]. For microbiological characterization and stability evaluation, the following microbiological analyses were performed: enumeration of aerobic mesophilic microorganisms according to ISO 4833-1:2013 [27]; enumeration of lipolytic microorganisms at 30 °C according to Bourgeois et al. 1991 [28]; enumeration of yeasts and moulds according to ISO 21527-1:2008 [29]; enumeration of osmophilic or osmotolerant yeasts and moulds according to ISO 21527-2:2008 [30]; enumeration of *Enterobacteriaceae* according to ISO 21528-2:2004 [31]; and the detection of spores of sulphite-reducing *Clostridia* according to NP 2262:1986 [32]. The results are expressed in logarithm of colony forming units per gram of spreadable cream (log c.f.u./g).

Physicochemical and nutritional analyses

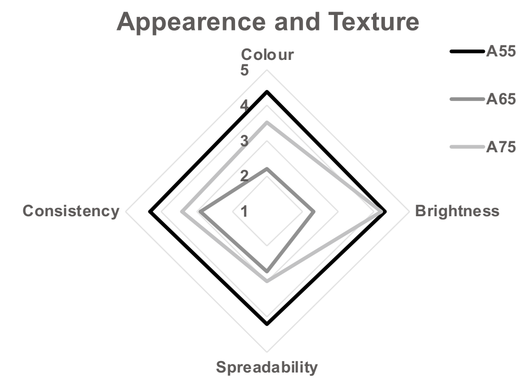
Physicochemical and nutritional analyses were performed for strawberry syrup spreadable cream (SSC). For physicochemical characterization, the parameters analysed were total acidity (TA) in (% w/w) oleic acid (spreadable cream) or % (w/w) citric acid (jam and jellies), according to NP No. 1412:1981 [33]; total soluble solid content (TSS in °Brix); pH measured on an emulsion prepared in isotonic solution of KCl 0,1 N using an immersion electrode. Nutritional assessment was performed according to AOAC 2002 [34]. The parameters analysed were caloric content, moisture content (935.36), crude protein (950.36), total lipids (935.38), carbohydrates, total fibre (950.37), salt content (930.23), and ash (930.23). For each parameter, three replicate experiments were carried out. The results were evaluated using Statistic version 7.0 program (Stat Soft Inc.). Mean and standard deviation were calculated for each analytical parameter.

Results

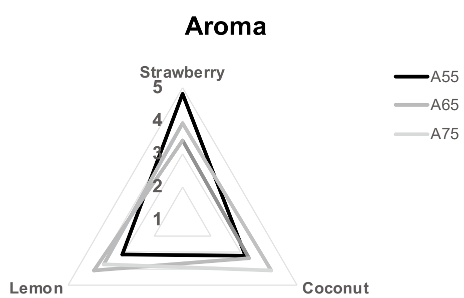
Sensorial evaluation

Sensorial evaluation is the consumer's first approach of a food product, whether colour is appealing or not and whether the product is bright or not, giving consumer an indication of its conservation. The rheological behaviour is critical for spreadable creams and the texture attributes are very important, namely, spreadability and consistency. For the current strawberry syrup spreadable cream (SSC), it is important to emphasize the predominance of strawberry aroma and taste. Less favourable scores can be associated with fat intensity, coconut and acidic taste, and aroma. Figure 1 presents the results of sensorial evaluation for the three prototypes of series No. 2 (A55, A65 and A75). Bearing in mind the desired organoleptic characteristics of this type of product, the untrained taster's panel gave the most favourable evaluation to A55 prototype.

Appearence and Texture				
Sample	**Colour**	**Brightness**	**Spreadability**	**Consistency**
A55	4.40	4.30	4.20	4.30
A65	2.20	2.30	2.70	2.90
A75	3.50	4.20	3.00	3.40



Aroma			
Sample	Strawberry	Coconut	Lemon
A55	4.80	3.20	3.10
A65	3.40	3.30	4.10
A75	3.90	4.10	3.74



taste				
Sample	Sweetness	Acid	Fat	Strawberry
A55	3.64	3.30	3.30	4.90
A65	3.64	4.60	4.20	2.40
A75	3.64	2.83	2.30	3.50

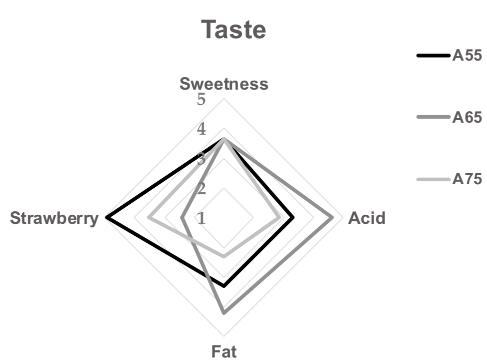


Fig. 1 Radar chart (**a**) appearance and texture, (**b**) flavours, and (**c**) taste attributes for A55 A65 and A75 prototypes (series no. 2)

Figure 2 presents the overall assessment results that confirms A55 as the final prototype.

Microbiological evaluation

The results for samples kept under refrigeration conditions are presented in Table 1. These samples remained stable at a temperature of about 5 °C compared to the sample after production (1 day). In the tests performed, *Enterobacteriaceae* were not detected, and the results were negative in 1 g; and spores of sulphite-reducing *Clostridia* were negative in 1 g. These indicators are relevant in terms of the production control, hygiene, and food safety. These results showed that samples had satisfactory microbiological characteristics and, so, quality, and microbiological stability of the final prototype can be guaranteed by good manufacturing practices.

Physicochemical and nutritional evaluation

The results of physicochemical and nutritional analyses for SSC are shown in Table 2.

Being a new product, there are no reference values to enable a comparison with the results obtained. Therefore, an analogy was established with vegetable-based spreadable creams (CSC) without additions, already on the market. The reference values for CSC were taken from US Patent De Groot WA (2006) [36] and from Food Composition Table (TCA) [37] of the National Health Institute Dr. Ricardo Jorge (INSA). In addition, the Portuguese legislation for jams and jellies was used—Portaria No. 1548/2002 [38] and Decreto-Lei No. 97/84 (jams and sweets) [39].

The results highlight the following:

– The pH values obtained were within the recommended range for this type of product, 4.2–4.4 [36].

– Total acidity results were much higher than the reference values of CSCs 1.0–2.2% ((w/w) oleic acid), according to TCA [37], and those of jellies were according to Portuguese legislation [38,39], as expected, since the added syrup was acidified.

– The average value of TSS for this new product is lower than the reference values of Portuguese legislation [38,39], which establishes a range of 60–70°Brix, emphasizing its potential as a possible substitute for jams and similar products.

– SSC caloric content was very similar to strawberry jam reference values, but significantly lower than the caloric content of CSCs, which is a beneficial and differentiating characteristic.

– The results obtained for lipid content of SSC were very promising in comparison to TCA-referred values [37] for vegetable-based spreadable creams (CSC).

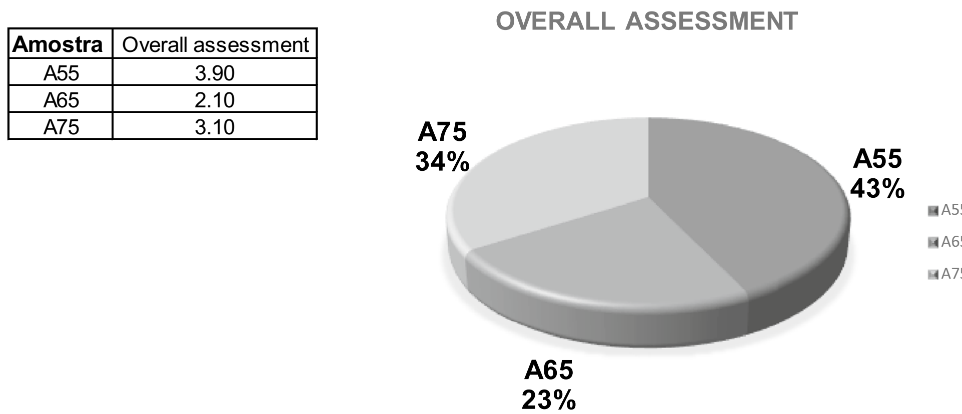


Fig. 2 Chart of overall assessment for A55 A65 and A75 prototypes (series no. 2)

Table 1 Microbiological stability tests results for strawberry spreadable cream

Time days	Enumeration of aerobic mesophilic microorganisms (log c.f.u./g) Mean ± Std	Enumeration of lipolytic microorganisms at 30 °C (log c.f.u./g) Mean ± Std	Enumeration of osmophilic or osmotolerant yeasts and moulds (log c.f.u./g) Mean ± Std	Enumeration of *Enterobacteriaceae* (log c.f.u./g) Mean ± Std	Guidelines of INSA*[35]
1	a	a	a	a	Satisfactory
30	a	a	a	a	Satisfactory
45	1.78 ± 0.01	2.78 ± 0.02	a	a	Satisfactory
90	2.38 ± 0.03	a	a	a	Satisfactory

a < 1 c.f.u./g

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Table 2 Physicochemical and nutritional characterization for strawberry spreadable cream

Parameter	Analytical method: [33] and [34]	Units per 100 g product	Strawberry spreadable cream (SSC) Results Mean ± Std	Vegetable-based spreadable creams* (CSC): [36] and [37] Reference values	Strawberry jam: [37,38] and [39]
pH	Potentiometry	–	4.37 ± 0.04	4.2–4.4	3.65–3.75
Total acidity	Potentiometric titration	% (w/w)**	3.68 ± 0.06	1.0–2.2	1.34
Total soluble solid content TSS	Refractometry	°Brix	51.53 ± 0.00	–	60–70
Caloric content	Calculation	kJ	1195	2600	1040
		kcal	286	632	245
Moisture content	935.36	g	49.97 ± 0.11	26.0	38.0
Total lipids	935.38	g	19.06 ± 0.65	70.0	0.0
Crude protein	950.36	g	0.15 ± 0.00	0.1	0.2
Carbohydrates	Calculation	g	28.3	0.3	60.5
Total fibre	950.37	g	2.22 ± 0.22	0.0	1.0
Salt content	930.23	g	0.0	3.0	0.0
Ashes	935.36	g	0.25 ± 0.02	–	–

kJ kilojoule (energy unit of the international system of units, 1 cal = 4.185 J)

*CSC 70% fat, with salt

**% (w/w) oleic acid (spreadable) or % (w/w) citric acid (jam and jellies)

Fig. 3 Strawberry spreadable cream (from left to right) end of production filling and food pairing

– The result obtained for carbohydrates in the final prototype (SSC) was about half of the value reported for strawberry jam in TCA [37].

– The result obtained for total fibre in the final prototype (SSC) was twice the value reported for strawberry jam in TCA [37].

These reported results suggest that the final prototype (A55) of this spreadable cream with added strawberry syrup (SSC, has the potential to be part of a healthy diet. Furthermore, sensorial tests carried out on food pairing and food design showed that SSC had a very pleasant strawberry flavour, good spreadability, and, in addition to its direct use, suitable for gastronomic applications [23,24].

Figure 3 shows the final prototype. From left to right: end of production, filling and packaging; gastronomic application—food pairing.

Discussion

To promote the diversification of new spreads, and aligned with current food trends, the present work developed a new and stable spreadable cream of vegetable origin, with addition of strawberry syrup. Simultaneously, it was shown that it may be possible to minimize the waste of agricultural products with low commercial value. This product allows better use of agricultural raw materials and stimulates the reducing of wastes, in line with the policies promoted by the European Union, vital to achieve the Sustainable Development Goals of the United Nations, particularly "12". Ensure sustainable consumption and production patterns". The choice of strawberry for syrup production is one of the examples of the valorization of agricultural products that would not be in conformity with the regulations for fresh market introduction. The results obtained for strawberry syrup cream (SSC), by analogy with reference values of similar products already on the market, show that this new spreadable cream with additions has several nutritional advantages. In fact, considering the reference for commercial spread creams (Table 2), the caloric and total lipid contents in CSC are both higher than in SSC, and crude protein and fibre are lower. The pH values are within the standard range required for CSC. This new product revealed a nutritional composition in the range of values recommended for a possible classification as healthy food as mentioned in references [1,2]. In general, the microbiological stability of the products in terms of safety and quality indicators was achieved. Sensorial tests were carried out on this prototype (A55) and the results indicated that this spreadable cream had a very pleasant taste and good spreadability, with future perspective of gastronomic applications. Finally, it is intended to proceed with scale-up by adjusting the manufacturing process to meet the requirements from the nutritional point of view, always ensuring the quality and food safety. In future, other spreads with other additions already developed will be described and presented in other manuscripts. The aim is to diversify the potential use of food emulsions, valorizing agricultural raw materials, in line with the necessary sustainability of the agro-industrial sector.

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Data availability statement The datasets generated and analyzed during the currently study are available from the corresponding author on reasonable request.

Declarations

Conflict of interest The authors declare no conflict of interest.

Compliance with ethics requirements This article does not contain any studies with human or animal subjects.

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