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Design and Development of an Eco-Innovative Sorghum Snack

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A new and sustainable cereal bar (named SOcrock) was created in the context of EcoTrophelia, an European competition originated from the EcoTroFood project (from the European Commission's Competitiveness and Innovation Framework Programme) and dedicated to student teams for creating prototype of food products with quality and environmentally friendly aspects.
The designed product recipe consisted only of white sorghum, powdered grape seeds, honey, and dark chocolate. This essential composition was formulated in order to boost nutritional added value such as presence of polyphenols, high fiber content, low level of sodium, and a low caloric intake, all within an organic product, free of gluten and preservatives.
A selected variety of white sorghum was the basic ingredient of the product: versatile, with nutritional properties similar to corn, sorghum has lower water requirements and withstands high temperatures brilliantly. In this product sorghum was transformed and used in three forms: as blown grain, as syrup (obtained by enzymatic hydrolysis of the grains) and as fiber (by-product of syrup production). Further innovation was the direct inclusion of grape seeds (by-products from distillery) that represents a simple solution for the recovery of low cost bio-active compounds. The preparation of the finished product was obtained by a semi-industrial processing line consisting in a cooker equipment (with hollow space in a diathermic oil bath) complete of planetary system and overturning head, cooling tunnel, and heat sealing packaging machine. The product impact on the ecosystem in terms of greenhouse gas emissions, water use, and exploitation of natural resources was evaluated. It resulted in a Type II environmental label which highlighted the product always falls in the best categories for sustainability. The developed product was awarded the bronze prize at the 2013 EcoTrophelia European final.

1. Product description

1.1 Recipe

SOcrock is an innovative and eco-sustainable healthy snack designed to be environmental friendly in all respects. Its recipe is made of the following ingredients: 40 % national white sorghum syrup (obtained by enzymatic hydrolysis of the grains), 28 % puffed national white sorghum, 20 % dark chocolate (cocoa mass, sugar, cocoa butter, emulsifier: soy lecithin, vanillin; Cocoa 56 %) for covering, 5 % local honey, 4.5 % national white sorghum fiber (by-product of the syrup production), 2.5 % powdered grape seeds (by-products from distillery). This composition results in the nutritional assessments (Table 1) which makes it possible to highlight to the consumer the high fiber content and the presence of phenolic compounds, as well as a calorie intake of 373 KJ/88 Kcal per bar only (4.4 % of Reference Intake of an average adult calculated on the basis of a daily intake of 8400 kJ/2000 kcal), according to the European Legislation (Parliament and Council Regulation 1169/2011).

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Table 1: SOcrock's nutritional information

Average values	100 g	per bar (22 g)
Energy	402 Kcal	88 Kcal
	1694 KJ	373 KJ
Fat	9.3 g	2.1 g
of which saturates	5.4 g	1.2 g
Carbohydrate	70.7 g	15.6 g
of which sugar	47.9 g	10.5 g
Dietary fiber	6.9 g	1.5 g
Proteins	5.3 g	1.2 g
Salt	0.003 g	0.001 g
Total polyphenols	0.034 g	0.007 g

1.2 Innovative raw materials

The basic ingredient of SOcrock is, therefore, national white sorghum which, alongside grape seeds, gives the product an healthy and eco-innovative connotation. SOcrock is a new and sustainable cereal bar, not only because it is prepared using a cereal always considered as minor (sorghum), but also because the added nutritional value is provided by ingredients obtained from what the food industry considers by-products (fiber and grape seeds). Considering the remaining known and standardized ingredients (honey and dark chocolate), the properties and the production processes of the innovative components were briefly described.
With a type of grain containing 11 % proteins, rich in carbohydrates and fiber, similar to wheat but gluten-free, white sorghum is a cereal of great potential, though it is little known. The use of a white variety which, compared to red sorghum, contains less tannins (usually responsible for astringent properties), allows to exploit the nutritional and eco-sustainable advantages of sorghum, without compromising the product taste. The best varieties of white sorghum were selected according to the content of essential amino acids of their proteins in order to overcome the strong dependence of the aminoacidic profile on growth conditions.
The choice of white sorghum as first raw material of reference for the production of SOcrock was inspired by the principles of sustainability and environment respect. The growing interest in sorghum cultivation is affected by the gradual increase in the time of production obtained, as a result of the development of cultivation techniques more suitable to different climatic conditions (especially for temperature and water availability) and the identification of better hybrids (Weinwurmb et al., 2014). The cultivation of common sorghum, which contains tannins, has always been confined to marginal lands, underestimating the great potential of the varietal selection: in recent years, studies have been conducted on the varieties of white sorghum that allowed to select hybrids (NO GMO) according to their amino acid content and their resistance to diseases and parasites. Sorghum interfaces as the main competitor of corn. At the same yield/ha (7-8 t/ha) sorghum has a lower request of water: the water consumption of maize is about 300 L of water per kg of dry matter, while the water consumption per unit of sorghum is lower than 250 L per kg of dry matter produced (ICRISAT/FAO, 1996).
Even the progressive increase in temperature is favorable for the cultivation of sorghum, characterized by high thermal requirements: to germinate and grow with acceptable readiness it is necessary to achieve a soil temperature of 14 °C, compared to 12 °C required for maize, the rising and flowering take place under optimal conditions with temperatures of 26-30 °C, but in bloom, unlike the corn, sorghum tolerates brilliantly also very high temperatures, up to 38 °C. The origin of the plant, in fact, is found in tropical areas of Central-Eastern Africa and in the mountains of central and western China, and it is mainly cultivated in the tropical areas of Asia and Africa, North America and Central-South America. Among the largest producers in the world, there are the Third World countries (e.g. Nigeria and Burkina Faso), so promoting the knowledge and use of sorghum could also have implications from the point of view of fair trade (Adegbola et al., 2013).
Another important ingredient is given by the grape seeds that make up about 15 % of the solid by-products resulting from wine making and are a source of phenolic compounds at low cost (Mironeasa et al., 2010). Rich in antioxidant compounds such as phenolic acids, flavonoids, procyanidins and resveratrol, depending on the variety, the seeds contain from 20 to 55 % of total polyphenols of the berry. In 100 g of grape seeds on average 75 mg of total polyphenols are found, mainly consisting of low molecular weight tannins and condensed tannins. Numerous studies have demonstrated that the phenolic compounds of grape seeds, in particular the procyanidins, have beneficial health properties (Yu and Ahmedna, 2013). Antioxidant compounds of grape seeds are able to withstand high temperatures: according to some studies (Kim et al., 2006) the heat treatment would even be able to increase the bioavailability of some compounds, increasing the total antioxidant capacity and leaving unchanged the polyphenols and flavonoids levels. Being mainly

constituted of lignin and cellulose, the use of ground grape seeds also has a substantial effect on dietary fiber intake and in particular on the insoluble fraction.

The grape seeds used for the preparation of SOcrock are by-products of the wine sector and come from an additional distillation process as a result of which they can be dried and intended for oil extraction. This last operation, however, does not exhaust the nutritional potential of grape seed and produces significant quantities of by-products not otherwise usable for human nutrition. Withdrawing the seeds after the distillation stage and using them as ground seeds in the product make it possible to recover bio-active compounds and also reduce this waste.

The residues of the food industry are the subject of study also for minimizing and preventing pollution effects associated with their disposal. Such residues, in fact, though not inherently hazardous, are characterized by a high content of organic matter and a production concentrated in specific periods of the year, causing polluting effects for the environment. However, for several years, many of these residues, in particular those of vegetable origin, are considered a good source of bioactive compounds (in particular antioxidants compounds of phenolic and fiber origin) with a high added value which, suitably recovered, can be reused along the food chain (Yu and Ahmedna, 2013).

In the past, significant efforts were made to explore the potential use of the polyphenols of grapes for the production of functional ingredients such as natural antioxidants for the fortification and preservation of foods. Generally, the production of extracts of pure polyphenols requires the use of organic solvents inducing, thereby, the onset of dangerous environmental problems (Spigno and De Faveri, 2007). To avoid the use of such solvents new techniques have been developed, which are, however, very expensive; direct inclusion of grape seeds (as carrier in respect of phenolic compounds) in the formulation of a product appears, therefore, as the simplest and most natural way to increase the content of antioxidants in the food.

2. Process description

SOcrock was born from an innovative ingredient base derived from sorghum: puffed sorghum, sorghum syrup and sorghum fiber. Thus, the processes needed to achieve each of them are briefly reported.

2.1 Puffed sorghum

For the puffed sorghum production carefully selected grains are used: any impurities, irregularities or defects are removed. The process of blowing occurs in three different phases. During the step of preheating sorghum is maintained in a rotating tube heated by direct flame, until it reaches the temperature of 95 °C for a time of 30 s. In the second phase, the hot cereal is transferred thus by gravity into the vertical blowing chamber, where a pressure device allows the introduction of steam at 15 bar. The grain remains in contact with the steam for 60 s. When opening the outlet valve, the pressure is lowered instantaneously (the classic outbreak) and the cereal swells (classic blowing). The blown product then is pushed into the drying chamber where it is collected. The part of product which hasn’t been blown can be recovered and used in specialized companies for the production of environmentally-friendly packaging as an alternative to polystyrene.

2.2 Sorghum syrup

The sorghum syrup is obtained by enzymatic hydrolysis of the grain. The unpeeled white sorghum, once germinated, is stored in the form of malt. After storage, the cereal undergoes milling and mashing in water at 60 °C, which facilitates the following step of fiber separation within a decanter: the insoluble fractions primarily composed of fiber (15 % of the total weight of the grain) and proteins (50 % of the protein material initially present) are removed by the gravity effect. The remaining proteins (soluble) are removed through a subsequent centrifugation step, followed by a concentration process (under vacuum evaporation at 70 °C). Finally the product is stored at 50 °C.

2.3 Sorghum fiber

What constitutes a by-product of the syrup production (fiber and protein) is currently allocated for animal feed companies, but it can be recovered and exploited. The protein material, if enzymatic attacked, can be used for amino acids production, while the sorghum fiber, when properly dried, represents a valuable source of bio-active compounds to be used in foods such as SOcrock.

2.4 Powdered grape seeds

The grape seeds used for SOcrock preparation come from a distillation process as a result of which they can be dried and appointed for oil extraction. The last operation, however, does not exhaust the potential nutritional of the grape seeds and rises significant quantities of by-products not otherwise used for human nutrition. The direct inclusion in food of grape seeds from distillation processes, represents a simple solution for the recovery of bio-active compounds and reducing waste. The grape seeds used in the recipe come to the distillery from the cellars, together with the grape skins. They are stored under anaerobic conditions until distillation, subsequently conducted in a vapour stream. The dregs are dried and then the separation of the skins from the seeds is carried out. To avoid the micro-organisms development and store the grape seeds in stable conditions, the seeds are sanitized through appropriate washing and dried at a temperature not exceeding 60 °C to obtain a residual moisture content minor than 3 %. The seeds are ground just before using.

2.5 Finished product

The supply of most of the raw materials and the production of the finished product are accomplished within a few kilometres. In order to obtain SOcrock it was necessary to proceed according to the following procedures.
The ingredients that constitute the liquid phase (sorghum syrup and honey) are mixed and heated to 215 °C for 16 min inside a cooker equipment (with hollow space in a diathermic oil bath) complete of planetary system (with a single spatula arm) and overturning head. Once sugar caramelization has been achieved, the solid phase consisting of blown sorghum, sorghum fiber and powdered grape seeds is added. The cooking time, varying from 7 to 9 min at a constant temperature of 215 °C, determines the grape seeds roasting and the development of the expected sensory characteristics. After the cooking step, the cooker is downloaded on a suitable stainless steel cooling surface, where to proceed to hot stretching and pulling the crispy until a uniform, smooth, compact product of the desired thickness is obtained. The next step with the hot cutting of crispy from which formed bars weighing about 15 g are obtained. All the portions trimmed during this process are recovered and reused in the subsequent cooking. In order to improve the attractiveness of our product, especially from the sensory point of view, a partial "vertical" bar coating with dark chocolate was provided, obtained through the use of a specific system for recoating, complete with tempering system and cooling tunnel. To be sufficiently fluid the covering chocolate must contain at least 34-36 % of cocoa butter. The coated product must be blown and examined before being introduced into the cooling tunnel where it passes from initial 10-15 °C, at intermediate 6-8 °C up to 15 °C in outgoing, to prevent the dew point. The final weight reached by bar is 22 g. After the production process, the product must be guaranteed in terms of hygienic quality, both nutritional and sensory quality. The packaging provided for SOcrock is a flow pack portion polypropylene Duplex, without secondary packaging.

2.6 Sensory characteristics

SOcrock looks as a bar of rectangular shape (10 cm long, 4 cm wide, 1 cm high and 22 g of weight) and consists of a grain (sorghum) and grape seed base, with a partial dark chocolate coating.
After a visual examination of the surface of the chocolate, it is possible to observe that it looks rough and patchy, but very glossy and firm. The exposed portion of corn and seeds is shiny, almost brilliant and very solid. Tactilely the surface covered with chocolate is very smooth and velvety, while the surface of cereal and seeds, though obviously irregular, is very firm. Biting the bar, it results very crisp and crumbly. Not at all sticky, it breaks effortlessly with chewing and is quickly soluble. In the part consisting of only corn and seeds, the perception of sweetness is very soft, but pleasantly persistent and balanced by notes of caramel and slightly toasted. The cover made of dark chocolate highlights both the sweet and the bitter perception, increasing the intensity of all the flavours perceived. This creates a pleasant contrast with the part of the bar only consisting of corn and seeds. The taste-olfactory persistence is long and the pleasant contrast on the different level of intensity, as well as the crispiness, the brittleness and the solubility, make this bar a pleasant and very attractive snack. Indeed, unlike most bars currently present on the market, the sickening and fatiguing perceptions of high sweetness, of stickiness, of gumminess and difficult friability, both to the touch and in the mouth, are absent

3. Environmental label

In the design of SOcrock an environmental label was applied on the packaging in order to promote and disseminate good practices of environmental responsibility, which are the basis of the implementation of the product (Riscazzi, 2012). The PAB environmental label, so named because created within “Piattaforma Ambiente per i Beni di largo consumo”, has been designed considering the findings of the literature and surveys analysis on sustainability and environmental communication issues carried out at European level. It is in fact a Type II environmental label according to the ISO classification (self-declared environmental claims).

Table 2: LCA results referred to a SOcrock bar calculated by Recipe Midpoint (H) v. 1.07 / Europe ReCiPe H method

Impact Category	M.U.	Value
Climate change	g CO2 eq	21.3
Ozone depletion	kg CFC-11 eq	$1.624 \cdot 10^{-9}$
Terrestrial acidification	kg SO2 eq	$6.9 \cdot 10^{-5}$
Fresh water eutrophication	kg P eq	$3.1 \cdot 10^{-6}$
Marine eutrophication	kg N eq	$2.0 \cdot 10^{-5}$
Human toxicity	kg 1,4-DB eq	$1.4 \cdot 10^{-3}$
Photochemical oxidant formation	kg NMVOC	$3.0 \cdot 10^{-5}$
Particulate matter formation	kg PM10 eq	$1.81 \cdot 10^{-5}$
Terrestrial ecotoxicity	kg 1,4-DB eq	$6.8 \cdot 10^{-7}$
Fresh water ecotoxicity	kg 1,4-DB eq	$2.7 \cdot 10^{-5}$
Marine ecotoxicity	kg 1,4-DB eq	$3.1 \cdot 10^{-5}$
Ionising radiation	kg U235 eq	$1.2 \cdot 10^{-3}$
Agricultural land occupation	m2a	$9.3 \cdot 10^{-5}$
Urban land occupation	m2a	$3.2 \cdot 10^{-5}$
Natural land transformation	m2	$2.7 \cdot 10^{-6}$
Water depletion	m3	$2.7 \cdot 10^{-5}$
Metal depletion	kg Fe eq	$1.0 \cdot 10^{-4}$
Fossil Energy resource depletion	kg oil eq	$3.9 \cdot 10^{-6}$

A label of this type meets a multi-criteria approach, i.e. a methodology that takes into account different types of environmental impact. The usual Carbon Footprint is supported by other indicators of impact, to enable recipients of information to evaluate on a larger spectrum in relation to the product. Data on emissions of greenhouse gases are accompanied by indicators of land use and biodiversity, water use and pollution, consumption of non-renewable resources, and so on. The fact of not restricting to a single indicator makes the evaluation more objective and less deviant. All information used to conduct the study, the conditions set up, the assumptions settled, the methodology chosen must be made available to anyone who request it, or who is simply interested. One possibility would be to publish such data on a support platform easily accessible as a website. The PAB label illustrates in an intuitive and immediate way the impact of the product on the ecosystem in terms of greenhouse gas emissions, water use and exploitation of resources, throughout the life cycle. Each category (air, water, soil) is obtained from the aggregation of several indicators that represent different environmental phenomena. The top bar represents the "total environmental cost”. The environmental impact is calculated through the analysis of LCA (Table 2) performed in according to ISO 14040:2006 (ISO, 2006a) and 14044:2006 (ISO, 2006b). This methodology considers all phases of the production process, avoiding partial assessments, sometimes distant from the real environmental impact of a process. The obtained results are compared with the impact of an average European citizen: if the impact of the snack is higher than the impact normally generated by a citizen in one hour, the product is considered completely unsustainable, conversely several categories of sustainability are defined. PAB environmental label has been created in compliance with the French AFNOR guidelines BP X30-323 (ADEME, 2010). The environmental impact assessments was carried out in compliance with ISO 14040:2006 (ISO, 2006a) and 14044:2006 (ISO, 2006b), using SimaPRo Software (PRé Consultants) and ReCiPe 2008 Midpoint H/A Europe (RIVM, CML, PRéConsultants, Radboud Universiteit Nijmegen and CE Delf) (Goedkoop, 2009) as method of impact assessment; for the Life Cycle Inventory (LCI) phase the Ecoinvent database (Ecoinvent Centre, 2007) is preferably used. The processing of data from properties and processes described in this work has produced an environmental label (Figure 1) which suggests that SOcrock always falls in the category of best sustainability.

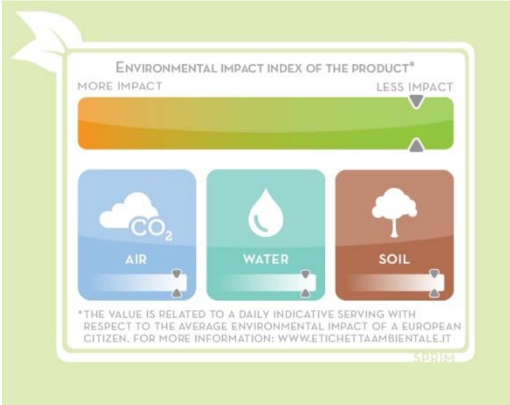

Figure 1: PAB environmental label referred to a SOcrock bar

4. Conclusions

Ecotrophelia Europe is a prestigious European-wide food innovation competition which challenges students to develop new, innovative, eco-friendly food or drink products with commercial potential. The sorghum crunchy snack with dark chocolate and powdered grape seeds, called SOcrock, was designed in this context. Optimising raw materials, ensuring sustainable processes and taking into account technical, taste, regulatory and packaging requirements SOcrock was awarded the bronze prise in the 2013 European competition. Therefore, it can be considered as an example to promote creativity and sustainability in the food industry.

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