New sustainable cosmetic products from food waste: a joined-up approach between design and food chemistry

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ABSTRACT

Through an integrated approach, which combines tools and techniques in design and food chemistry disciplines, new sustainable products have been experimented in cosmetic field.
The design tools, acting in multiple and diversified fields, aim at valuing and increasing capabilities by creative training for generating sustainable and reproducible goods, whereas the investigation of the chemical composition of foods and their by-products is one of the main goals in food chemistry research. In this context, agri-food sector by-products are an inexhaustible source of bioactives, whose re-use, as alternative sources of low-cost and bio-sustainable active ingredients, is desirable in the nutraceutical field. Furthermore, the recycling of waste could reduce its environmental impact and the related disposal costs. The collaborative methodology is prompt to convey a new concept of wellness and body care through a new eco-oriented product production in which food winter-wastes are investigated for their cosmeceutical value for the formulation of green-cosmetic products. The paper reports the experience carried out in the design and food chemistry laboratories.
Key Words: green-cosmetic products, food waste, bio-sustainable active ingredients.

1. INTRODUCTION

Recent studies and reports on companies in the cosmetic sector demonstrate a steady growth in turnover both nationally and internationally, with import and export flows extending globally. The constantly growing market trend is due to various causes, which, over time, have generated a consolidated position in the cosmetic sector, whose market has a heterogeneous and geographically diffused dimension, with a very high European share. Made in Italy cosmetic sector is characterized by companies that invest in creativity and innovation, and implement design-oriented strategies (Verganti, 2009). In fact, a positive dynamic record in terms of production and exports seems to be related to creativity, safety and innovation, which are determinants to generate products with a high know-how content and in line with the evolution of consumer demand. In fact, sustainable production, traceability of ingredients, and the ethical code of companies define consumer choices and the growing demand for eco-friendly cosmetics (Cosmetica Italia, Beauty Report 2018). Indeed, cosmetics have a massive environmental impact as their production involves different aspects, among which ingredients choice, which in turn affect the acquisition of resources, and their processing. Suitable packaging and communication, the product distribution and its disposal must not be neglected, as well as the fate after use. Recent studies have correlated the use of sunscreens based on chemical filters in bathing areas near the reef and the progressive whitening of corals, a phenomenon, which risks destroying 10% of coral reefs (Danovaro et al., 2008). Thus, sustainability design requires an accurate analysis of the entire production chain and an input and output evaluation action consistent with the design strategies. The application of sustainable strategies in every phase of the production process - from the acquisition of the resources for the cosmetic formulation to the choice of bottles and packs made of biodegradable, recyclable and eco-compatible materials until the product disposal phase - lead to an overall assessment of the functional units that make up the product and a balance of the impact on the environment in all phases of life.

2. ECO-ORIENTED STRATEGIES OF PRODUCTIVE CHAINS

Recently, cosmetics field, commonly considered as hardly unrelated or antithetical to sustainability and environmental protection, broadly have shifted its manufacturing models, favouring sustainable actions. In this context, new brands are founded for which sustainability is a distinctive identity feature. Ingredients, processes, packaging materials, labels printing, distribution, and all strategies, involved in the products life cycle assessment, are defined with a sustainable and ethical approach. The importance of supply chains, from ingredients to chemical formulation, from extraction processes to manufacturing of cosmetic lines, from the distribution strategies to the product dismission, are the main part of new cosmetics products success. Thus, the role of design is essential like the gradual extension of the eco-oriented criteria to various manufacturing sector. Through the product Life Cycle Design approach (LCD), innovative concepts of life cycle and functional thinking are developed and new way to products production and use are shared (Vezzoli, 2010). "Innovation and the related design process of creative destruction lead to new ideas, new entrepreneurs and new business models, thus contributing to the establishment of new markets and the creation of new jobs in a sustainable way. Sustainable innovation is, therefore, the key to enable green and growth to go hand in hand, and design has gained the multidisciplinary expertise to drive it in the right way" (Gaiardo, Tamborrini, 2016).

Companies' commitment towards environment and the promotion of local producers' communities is conveyed through communication and awareness campaigns headed for sustainable and ethical behaviour. This is the case of multinational brands such as Aveda, the cosmetic company, which was one of the first companies in the world to promote environment safekeeping in its production processes. Another example is the French company World Wild Men cosmetics, Organic & ethical skincare for men, which in addition to the proposal of products following eco-oriented principles in design and production (Vezzoli 2017), transfers, through an ironic communication, a message related to individual choices safeguarding the environment and daily action. The WWM cosmetics select the ingredients and their origins, use eco-oriented packaging and all the labels are printed on recycled paper, issued from sustainable woods, printed with vegetal/ecological ink.

Many Italian companies, e.g. Davines, also follow sustainability proposing an ethical code that can guide consumers and beauty centers towards greater awareness of the impact of wellbeing behaviours on the environment. Since its foundation, Davines has promoted eco-oriented strategies in the processes, in the choice of single-material packaging to be used for different uses at the end of its life and a manifesto of behaviour for beauty centers. Companies that choose to orient themselves towards sustainable production act through a careful ingredients choice, reducing resources use, optimizing packaging by compatible, recyclable eco-materials. Sustainable strategies in formulations are cold process, time and energy saving, ingredients selection from green and local companies and the new concept development of products and formulations able to optimize materials in the process and in the use. It is necessary to evaluate the inputs and the outputs of all stages in the product definition and to use a product

life cycle design approach (Vezzoli, Ceschin, Cortesi 2010).

3. GREEN-COSMETIC CONCEPT FORMULATING

A multidisciplinary and integrated approach is the driving force of the proposed new development concept in the cosmetics field. According to eco-oriented principles, and based on agri-food sector analysis, bio-sustainable active ingredients have been used in a new skin care line. Design and Food Chemistry "at a table" to convey a new concept of wellness and body care: kitchen waste recycling reduces new products environmental impact. The collaboration between Food Chemistry laboratory - Department of Environmental Biological and Pharmaceutical Sciences and Technologies - and design laboratory – Department of architecture and industrial design - has experimented, thanks to well-integrated skills and competences, new sustainable and fully natural cosmetic products. The obtainment of new sustainable and fully natural cosmetic products aims to introduce new behaviour in the daily life and to transfer the awareness about environmental effects related to the reduction, repurpose and recycling of the food waste (Wever, 2012). This was from eco-friendly extraction of chosen waste material, the deep chemical characterization of extracts therefrom, and the assessment of their antiradical properties. The exploited approach is an opportunity for influencing user's behaviour and for spreading a new concept of wellness and body care.
"Feed" project takes into account that skin healthy state requires antioxidants' constant supply, as oxidative stress favours skin aging processes and other disorders. Ultraviolet solar radiation and an unhealthy lifestyle are exogenous factors harmful to the skin, which is constantly exposed to changes in connective tissue due to the formation of lipid peroxides and reactive oxygen species (ROS). The topical application of antioxidants is an efficient strategy to enrich the endogenous skin system in the prevention of oxidative stress related diseases. Among natural molecules, phenolic compounds are main actors in preventing free radicals formation (Pacifico & Piccolella, 2015). Thus, their recovery from alternative but rich source as kitchen waste and their employment in antioxidant products for face aim at protecting skin from exogenous radicals (UV rays, pollution, smoke), as well as at preventing and delaying epidermal cells aging. "Feed" is articulated in three main products: 1) a soap-scrub enriched with exhausted coffee powder for a cleansing and exfoliating treatment; 2) a peel off mask with extract obtained from broccoli wastes for revitalizing and soothing treatment; 3) a cream with orange peel extract with moisturizing and elasticizing effects (figure 1). Food Chemistry laboratory of the University of Campania "Luigi Vanvitelli" realised the cosmetic references with the idea to create a kit lasting about a month, in which each product is a phase of reconstituting and protective treatment from UV rays and polluting sources. In addition, the products can also perform an anti-aging action.

[Figure 1] *Feed project 2018,* Designer *Claudia Derrico, final work master degree in Design for Innovation, University of Campania Luigi Vanvitelli*

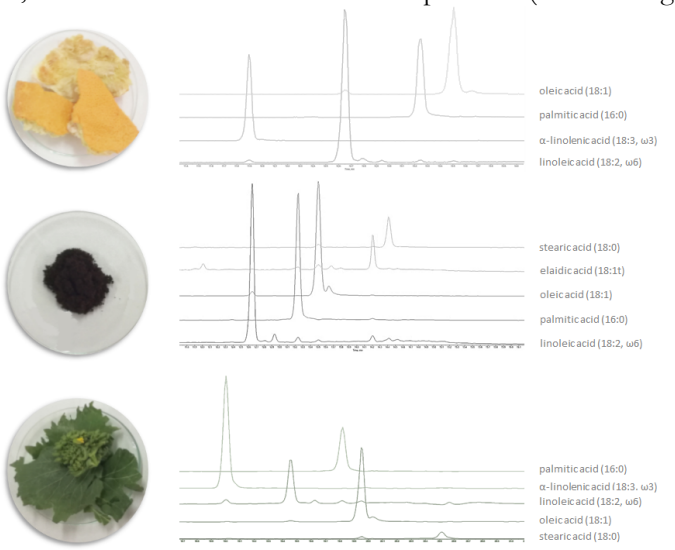
3.1. Sustainable formulating: research steps and test

The recovery and re-use of bio-active (poly)phenols from kitchen plant wastes could be pivotal for establishing new cosmetic references, in the awareness that such molecules can exert cosmeceutical action in dermo-cosmetics and are good candidates to replace synthetic compounds, which have demonstrated possible negative effects on health and environment. Indeed, kitchen food plant wastes are very rich in sugars, minerals, organic acids, fibers and bioactive compounds, exactly like their edible counterparts. Herein the potential use of food waste from oranges, broccoli and coffee was evaluated in the formulation of cosmetics commonly used in personal care: an anti-aging face cream, a mask and a scrub, respectively. In the consciousness that the bioactivity of a plant extract is in its chemistry, the alcoholic extracts from orange peels (*Citrus sinensis*), coffee grounds (*Coffea arabica*) and broccoli

leaves/stems (*Brassica oleracea* var. *italica*), prepared by ultrasound-accelerated maceration, underwent chemical characterization through the combination of ultra-high-pressure liquid chromatography (UHPLC) and high-resolution tandem mass spectrometry (HRMS) techniques. Extracts from orange, coffee and broccoli wastes were also tested for their scavenging capacity against DPPH (2,2'-diphenyl-1-picrilhydrazyl) radical and ABTS radical cation (2,2'-azinobis-3-ethylbenzothiazolin-6-sulfonic acid).

3.2. Extracts' characterization

Orange peels are mainly rich in flavones and glycosylated flavonols, differing in B and C rings oxidation degree and glyconic moiety, its position and the glycosidic bond type (*O*- or *C*-glycoside). Rutin appears to be the main component, followed by naringenin 7-*O*-rutinoside and apigenin 6,8-di-*C*-glucoside. Minor components include rutinosyl derivatives of luteolin- and myricetin. Glycosylated flavonoids characterized broccoli waste extract. UHPLC-HRMS analyses highlighted the presence of flavonols (kaempferol, quercetin and isorhamnetin) mono- and di-*O*-glycosylated, in which the saccharide moiety is likely to consist in sophorose or gentiobiose. In addition, the presence of kaempferol and quercetin glycosides differently acylated was evidenced. Coffee grounds' extract chemically differs from the previous ones due to the presence of phenolic acids instead of flavonoids. In particular, chlorogenic acids, and caffeoyl-shikimic acids were identified as constituents of the coffee grounds' extract.
Moreover, besides the presence of the more polar phenols and polyphenols, the content of fatty acids, both saturated and mono- and polyunsaturated, was detected in all the waste extracts. The content of oleic acid (18: 1) and linoleic acid (18: 2, ω6) is almost comparable in the three samples, whereas α-linoleic acid (18: 3, ω3), which seems completely absent in coffee grounds, reaches the maximum content in broccoli waste. Palmitic acid, the only saturated fatty acid (16:0) detected in appreciable amounts, is mainly present in the *Brassica oleracea* extract (figure 2). The presence of fatty acids gives added value to the investigated formulations. In fact, linoleic and α-linolenic acid have different functions in relation to skin care, such as the ability to influence the metabolic processes of the skin and to promote the activity of vitamins A and E. They are also used in anti-inflammatory cosmetic formulations, against skin lesions of dry skin, in the treatment of dermatitis and psoriasis (Kiezel-Tsugunova et al., 2018).



[Figure 2] *Fatty acid occurrence in wastes of* Citrus sinensis*,* Coffea arabica *and* Brassica oleracea

The three samples exert a dissimilar antiradical effect against the two probes considered, albeit dose-dependent in both cases. Flavonoid extracts from orange and broccoli wastes were not able to fully neutralize DPPH•, whereas coffee extract appears effective. With respect to antiradical activity towards ABTS radical cation, extracts from *Citrus sinensis* and *Brassica oleracea* wastes seem to have comparable reducing capacities, slightly in favour of the latter, as evidenced by their relative ID_{50} values (extract dose capable of inhibiting 50% of the present radical in the reaction mixture) equal to 47.9 and 32.8 μg/mL, respectively. Coffee grounds extract scavenges efficaciously both target species, showing an activity comparable to that observed for Trolox®, a synthetic analogue of vitamin E with well-known antioxidant capacity, used as a reference standard. The calculated ID_{50}s are 27.0 (vs. DPPH•) and 11.4 μg/mL (vs. $ABTS^{\bullet+}$). The results obtained are in agreement with literature data, according to which the chlorogenic acids present in coffee and its waste, by virtue of their chemical structure containing catechol units, are particularly reactive towards free radicals, which are reduced to harmless species (or at least less reactive) following the donation of available hydrogen atoms (Tajik et al., 2017). The lower activity of the other two samples studied could be explained based on their richness in glycosylated flavonoids.

3.2. Extracts' preparation

Kitchen wastes, once collected and cleaned, underwent freeze-drying (FTS-System Flex-Dry, SP Scientific, Stone Ridge, NY, USA). Lyophilized underwent ultrasound assisted maceration. To this purpose, for each sample, three extraction cycles (30 min each) were performed in a 40 kHz ultrasonic bath (Branson M3800, Carouge, Switzerland) with methanol (MeOH). Extracts obtained underwent UHPLC-HRMS-based metabolic profile analyses and antiradical power assessment.

3.3. UHPLC-HRMS analyses

Extracts from table wastes (10.0 mg), solubilized in pure methanol (1.0 mL), underwent UHPLC-ESI-QqTOF-MS/MS analysis. To this purpose a Shimadzu NEXERA UHPLC system was used with a Luna® Omega Polar C18 column (1.6 μm particle size, 150 × 2.1 mm i.d., Phenomenex, Torrance, CA, USA).
The mobile phase consisted of a binary solution A: H_2O (0.1% HCOOH), B: CH_3CN (0.1% HCOOH). In the extracts of *Citrus sinensis* and *Coffea arabica*, the elution was carried out as detailed below: starting from 5% of B a linear gradient was performed up to 95% B in 15 min, continuing for 1 min before re-equilibrating the system (1 min). For the extract of *Brassica oleracea* var. *italica*, the separation was carried out always starting from 5% B, following an isocratic elution for 15 min, then reaching 40% B in the next 5 min, before re-balancing the system for 2 min. In all the cases, a flow rate of 0.5 mL min^{-1} and an injection volume of 2.0 μL were set. The MS analyses were conducted using the AB SCIEX TripleTOF 4600 system equipped with a DuoSpray™ ion source operating in a negative electrospray ionization mode, with a declustering potential (DP) of 70 V, a collision energy (CE) of 45 V and a CE spread (CES) of ± 25 V. Data processing was performed using the PeakView® - Analyst® TF 1.7 Software.

3.4. Assessment of DPPH radical and ABTS radical cation scavenging ability

The scavenging capacity of the extracts prepared from the waste of *Citrus sinensis*, *Coffea arabica* and *Brassica oleracea* var. *italica* against DPPH radical and ABTS radical cation was carried according to Pacifico et al. (2019). Trolox®, a synthetic vitamin E analogue with known antioxidant capacity, was used as positive standard. Tests were carried out performing three replicate measurements for three samples (n = 3) of the extract (in total, 3 × 3 measurements). Results are the mean ± SD values. ID_{50} values, based on the percentage decrease of the initial probes' absorption by the different concentrations of the test samples (1.56, 3.125, 6.25, 12.50, 25, 50 and 100 μg/mL) were also calculated.

3.5. Cosmetic references

For soap scrub preparation, sodium hydroxide, dissolved in distilled water, and EVO oil were emulsified together with 2.6 grams of coffee grounds. The obtained mixture was poured into the appropriate mold. Face cream preparation was based on almond oil and beeswax, which were dissolved in a bain-marie, and then added to boiled distilled water, together with drops of *Lavandula angustifolia* essential oils and the orange peel extract. Peel off mask preparation was realised using two and a half tablespoons of milk, brought to boil, and mixed to food jelly and broccoli extract.

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