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Characterization of phenolic compounds in vegetable by-products: *in vitro* evaluation of biological activity and their possible application in novel foods

Alessandro Guglielmetti (alessandro.guglielmetti@unito.it)
DISAFA - Dept. of Agricultural, Forest and Food Sciences, University of Turin, Italy
Tutor: Prof. Giuseppe Zeppa

The aim of this PhD thesis research project is the valorization of some coffee, hazelnut and cocoa by-products. In particular this thesis will consider coffee silverskin, hazelnut testa and cocoa bean shell as ingredients for some foods. For every by-product will be evaluated the bioaccessibility of phenolic compounds content and their biological activity on human cells-lines; alike will be evaluated technological, compositional and sensory effects due to the addition of by-products in food models.

Caratterizzazione di composti fenolici presenti in sottoprodotti di origine vegetale: valutazione *in vitro* dell'attività biologica e loro possibili applicazioni in alimenti innovativi

L'obiettivo di questo progetto di ricerca di dottorato è quello di valorizzare alcuni sottoprodotti di caffè, nocciola e cacao. In particolare questa tesi considererà il silverskin di caffè ed il perisperma di rivestimento del cacao e della nocciola come ingredienti di nuovi alimenti funzionali. Per ogni sottoprodotto verrà valutata la bioaccessibilità dei composti polifenolici presenti e la loro attività biologica su linee cellulari umane, nonché l'effetto tecnologico, compositivo e sensoriale dato dalla loro aggiunta in alimenti modello.

1. State-of-the-Art

The processes of the food industry cause the formation of by-products that constitute additional costs of disposal for the company and environmental problems. In this regard, many studies are focusing their attention on the value of food by-products and on the identification of possible alternative uses. In processing of food products such as coffee, cocoa and hazelnut are eliminated certain by-products rich in bioactive compounds: in particular, the roasting of coffee leads to the elimination of the last layer of the seed skin, the "silverskin"; alike the seed of the cocoa, following a drying process, is divided into two parts (cotyledons), eliminating the outer pericarp. Finally also the hazelnut is constituted by a seed covered by a pericarp which is eliminated in the roasting phase. These by-products are rich in polyphenolic compounds with high antioxidant activity. Particularly hazelnut testa is characterized by phenolic acids, flavonoids, and proanthocyanidins (Yurttas *et al.*, 2000), in the silverskin are mainly content chlorogenic acids (Bresciani *et al.*, 2014) while cocoa bean shell is characterized by proanthocyanidins, catechin and epicatechin (Ortega *et al.*, 2008).

Many studies have highlighted the benefits to human health due to a diet rich in polyphenols. In particular, it has been shown a preventive effect against diseases with a large incidence such as diabetes, cardiovascular disease and cancer. For this reason, in recent years, some studies have considered these by-products as ingredients in some foods (Table 1).

Table 1 *Application of coffee silverskin, hazelnut testa and cocoa bean shell in some foods*

By-product	Food	Reference
Coffee silverskin	Beverage	Martinez-Saez <i>et al.</i> (2014)
	Bread-making	Pourfarzad <i>et al.</i> (2013)
Hazelnut testa	Bread-making	Anil (2007)
Cocoa bean shell	Biscuits	Kärkliða <i>et al.</i> (2012)

For this reason it is of fundamental importance to be able to fully exploit these food by-products.

Thus, this PhD thesis project will be directed to:

- Define polyphenolic composition of the three by-products integrating bibliographic data.
- Evaluate digestibility and bioaccessibility of phenolic compounds content in the three by-products with the development of an *in vitro* digestion model.
- Define the biological activity of by-products digested on human cell-lines.

- Define the chemical, physical, microbiological and sensory effects due to the addition of coffee, cocoa and hazelnut by-products in some foods.

2. PhD Thesis Objectives and Milestones

Within the overall objective mentioned above this PhD thesis project can be subdivided into the following activities according to the Gantt diagram given in Table 2.

- A1) **Bibliographic research:** The most important papers, books and documents on coffee, hazelnut and cocoa by-products (characterization and application studies) were collected and read.
- A2) **By-product collection and transformation:** Coffee silverskin, hazelnut testa and cocoa bean shell (indicated in the Gantt diagram with different cell styles) will be collected in different times and milled to form flours with appropriate size.
- A3) **By-product characterization:** all collected sample will be characterized and chemical characterization (A3.1), bioaccessibility evaluation (A3.2) and biological activity (A3.3) will be defined.
- A4) **Food application:** by-products will be added to yogurt (A4.1), biscuits (A4.2), chocolate (A4.3) and pasta (A4.4).
- A5) **Characterization of functional foods:** Moreover will be evaluated chemical composition (A5.1), phenolic composition (A5.2), microbiological interaction (A5.3), shelf life (A5.4) and sensory properties (A5.5) of new foods formulated with by-products.
- A6) **Writing and Editing** of the PhD thesis, scientific papers and oral and/or poster communications

Table 2 Gantt diagram for PhD thesis project.

Activity	Month	2014												2015												2016											
		G	F	M	A	M	G	L	A	S	O	N	D	G	F	M	A	M	G	L	A	S	O	N	D	G	F	M	A	M	G	L	A	S	O	N	D
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
A1)	Bibliographic research	■																																			
A2)	By-product collection and transformation	■												■												■											
A3)	By-product characterization													■												■											
	1) Chemical characterization													■												■											
	2) Bioaccessibility evaluation													■												■											
	3) Biological activity													■												■											
A4)	Food application													■												■											
	1) Yogurt													■												■											
	2) Biscuits													■												■											
	3) Chocolate													■												■											
	4) Pasta													■												■											
A5)	Characterization of functional foods													■												■											
	1) Chemical composition													■												■											
	2) Phenolic composition													■												■											
	3) Microbiological interaction													■												■											
	4) Shelf life													■												■											
	5) Sensory properties													■												■											
A6)	Thesis and paper preparation	■												■												■											

Coffee silverskin
 Hazelnut testa
 Cocoa bean shell

3. Selected References

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