ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA
ALMA FOOD

Biotechnological conversion of byproducts of plant origin in to novel foods with improved, functional and nutritional properties

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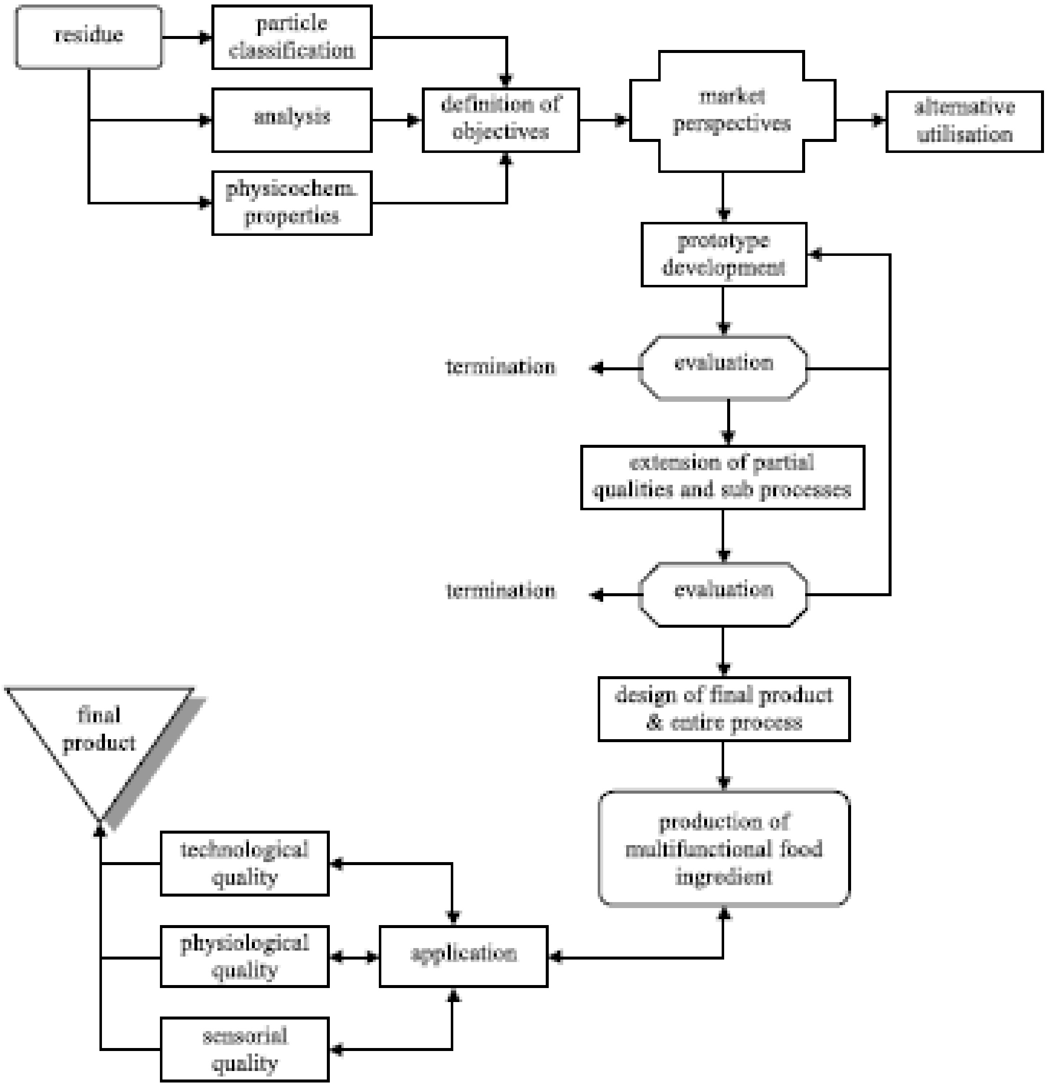
The project intends to tranform byproducts of the food industry, and namely fruit and cereal by product in to **novel foods** differenziated in terms of sensorial and textural properties and characterized and valuable functional attitudes due to the enrichment in polyphenols, vitamins, aminoacids, fibers, with improved functional and nutritional properties and characterized by valuable functional attitudes due to the enrichment in polyphenols, vitamins, aminoacids, fibers and microbial metabolites.

- New low cost technologies will be used to give rise more stable products with extended durability

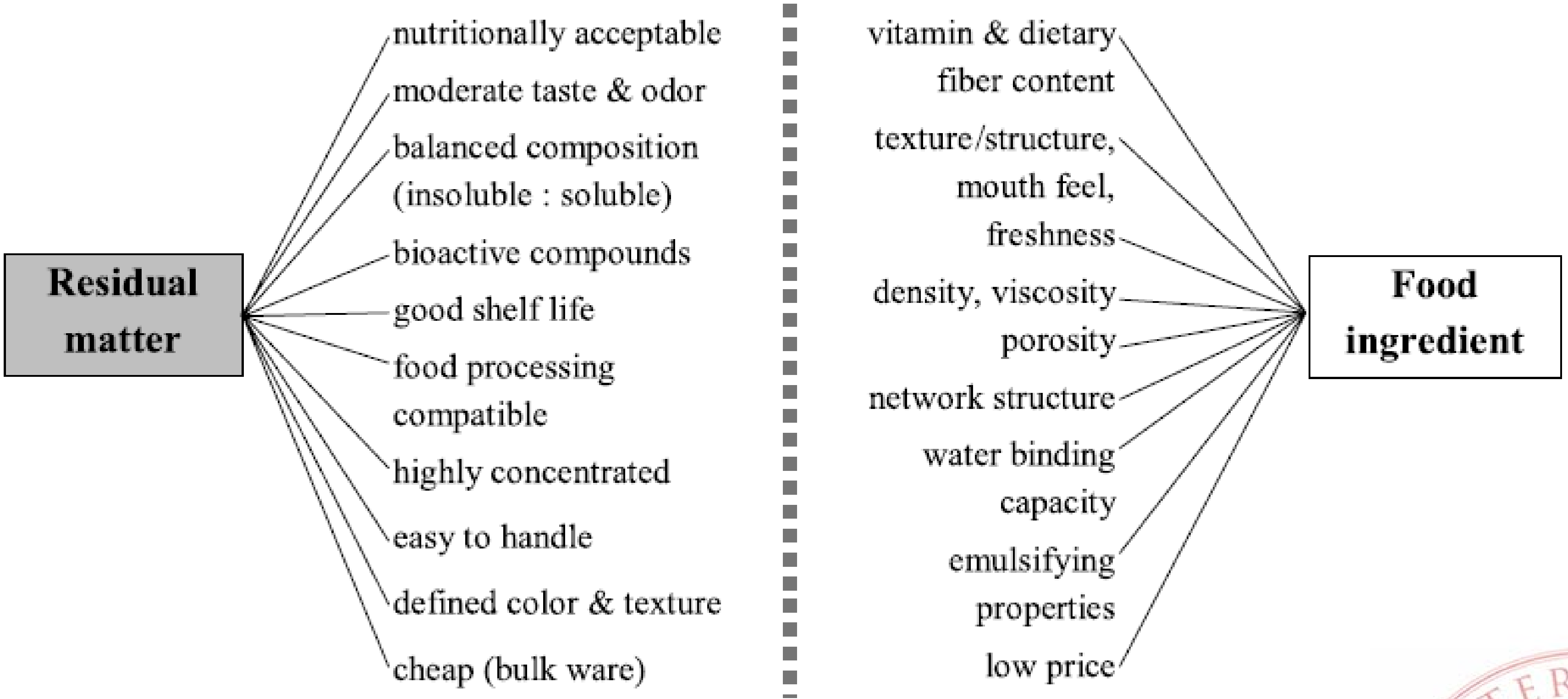
- A microbiological and chemical risk assessment will be performed in order to assure consumer safety

Strategy for the development of multifunctional food ingredients made of vegetable residues: the upgrading concept



Food properties and quality influenced by multifunctional food ingredients
Operating areas of multifunctional food ingredients due to food properties and quality
(1) Nutritional and healthy quality, e.g. vitamin content, dietary fibre content (2) Food product structure, e.g. porosity, network structure (3) Sensorial properties, e.g. texture/structure, mouth feel, freshness (4) Physical properties, e.g. density, viscosity (5) Processing properties, e.g. water binding ability, emulsifying properties

Natural properties of vegetable waste (average) and food properties and quality being influenced by multifunctional food ingredients



Content of several relevant compounds in vegetable residues (Al-Wandawi et al., 1985; Clemente et al., 1997; Henn, 1998; Larrauri et al., 1999; Lu and Foo, 1997; Saura-Calixto, 1998)

Residue	Plant phenols (flavonoids, phenol carboxylic acids)	
	Colourless	Coloured
Apple pomace	0.724%[a] (Lu and Foo, 1997); 350.6 mg/kg[b], FA 8.0 mg/kg[b] (Lucarini et al., 1999)	
Carrot pomace		β-carotene[a] 3 mg/kg
Chokeberry pomace		Anthocyanins 9.1 g/kg (Máriássyová et al., 1999b)
Cocoa bean shells	Tannins 3.1%[a]	Leucoanthocyanidin (Nambudiri and Shivashankar, 1985)
Elderberry pomace		Anthocyanins 16.6 g/kg (Máriássyová et al., 1999b)
Grape pomace	2%[a]; 11.7%[a] (Zeller, 1999)	Anthocyanins
Grape skins	25–35%[a] (Anon., 1999)	Anthocyanins
Grape fruit peel	Naringin 0.07–1.7%[b]	Carotenoids
Green tea	10.1–21.6%[a,c]	
Honeysuckle pomace		Anthocyanins 8.0 g/kg (Máriássyová et al., 1999b)
Mango peel	5.5%[a]	Carotenoids
Olive press cake	0.3%[b]	Anthocyanins
Orange peel	Hesperidin 1.3–2.4%[b]/1.7–2%[a] (Manthey and Grohmann, 1996); Nobiletin[d] 32% (Manthey and Grohmann, 1996)	Carotenoids
Red beet pomace		Betanine 414.3 mg/kg[b] (Máriássyová et al., 1999a)
Sugar beet pulp	FA 0.36%[a] (Couteau and Mathaly, 1998)/8 g kg[a] (Thibault et al., 1998)	
Tomato skins	210.8 mg/kg[b] FA 3.7 mg/kg[b] (Lucarini et al., 1999)	Lycopenes[b] 120 mg/kg (Al-Wandawi et al., 1985), 80 mg/kg[b] (Lucarini et al., 1999)

FA = ferulic acid.

[a] Related to dry mass.

[b] Related to fresh good.

[c] Depending on the tea species and seasonal changes. Tea flavonoids are catechin, gallocatechin, epicatechin, epicatechin gallate, epigallocatechine, epigallocatechin gallate, the latter of which is always the largest fraction (Chu and Juneja, 1997).

[d] In orange peel oil solids (hexane extracted).

Selected flavours, production rates and selling prices

Flavour	Feed conc.[a]	Selling price in US$/kg	Year
Vanillin	230 mg/l (Asther et al., 1997)	Natural extract 4000 (Asther et al., 1997)	1996
	560 mg/l (Thibault et al., 1998)		1998
γ-Deca lactone	6 g/l	Biotechnical 6000	1992
Isoamyl acetate	5.22 mg/kg DM		1999
	6.25 mg/l (Christen et al., 1997)		1997
β-Phenethyl alcohol	2 g/l	Biotechnical 2500	1994
2-Heptanone	17 g/l	Synthetic 39	1991
Ethyl butyrate	–	Biotechnical 180	1996

(–) No data available.

[a] Related to biotechnical production.

Flavours and biofine chemicals produced by SSF of vegetable residues (selection)

Year	Residual matter	Description/conversion principle	Product
1991	Apple pomace (Almosnino and Belin, 1991)	Enzyme system to degrade the precursors linoleic and linolenic acid	Volatile aldehydes, alcohols
2000	Apple pomace, spent malt grains (Stredansky et al., 2000)	*T. elegans* CCF 1456 degraded the substrate in a ratio of 3 to 1 (AP to SMG), precursor peanut oil even increased the yield	γ-Linolenic acid was produced in a yield of 5.17 g per kg dry substrate; with peanut oil precursor 8.75 g per kg DM
1998	Carrot, citrus, pineapple pomace (Mukherjee and Sen, 1998)	*Aspergillus* spp. Mass multiplication	Biocontrolling agent in cultivation of melons
2000	Cassava bagasse, apple pomace (Christen et al., 2000)	Four strains of *Rhizopus*, two residues and two precursors, mixed substrate combinations	Volatile carbons as flavours; acetaldehyde, ethanol, propanol, esters
1997	Cassava bagasse, wheat bran and sugarcane bagasse (Christen et al., 1997; Bramorski et al., 1998)	*C. fimbriata*, ability to generate fruity aromas in dependence on the substrate used	Banana flavour and fruity complex flavours, up to 10-fold higher production compared to ripe bananas
1994	Citrus, apple, sugar beet pomace (Grohmann and Bothast, 1994)	Microbial conversion by enzymatic hydrolysis	Pectin, substrate, liquid biofuel
1998	Cranberry pomace (fish offal) (Zheng and Shetty, 1998)	*Trichoderma viride*, *Rhizopus* $CaCO_3$ was added as neutraliser, water for a_w adjustment	Polymeric dye decolourising isolate for wastewater treatment, extracellular enzymes
2001	Linseed cake, castor oil cake, olive press cake, sunflower cake (Laufenberg et al., 2001)	*Moniliella suaveolens*, *Trichoderma harzianum*, *Pityrosporum ovale* and *Ceratocytis moniliformis* form decalactones (problems with phenolic components)	Acceptable yields on olive press cake and castor oil cake. δ- and γ-decalactone (up to 1 g per kg DM) are produced
1998	Olive cake, sugarcane bagasse (Cordova et al., 1998)	Lipase degrading fat in olive cake	Enzyme product applied in bakery goods, confectionery, pharmaceuticals
1999	Olive pomace (Haddadin et al., 1999)	Four micro-organisms, delignification, saccharification with *Trichoderma* spp., biomass formation with *Candida utilis* and *Saccharomyces cerevisiae*	Crude protein enriched from 5.9% to 40.3%. Source for animal fodder
1995	Pineapple waste (Tran and Mitchell, 1995)	*A. foetidus* produces citric acid 16.1 g/100 g DM and 3% methanol	Pharmaceuticals, food industry, preserving agent
1997	Potato waste (Lucas et al., 1997)	Amylases	Bakery goods, breweries, textile industry
1997	Sugar beet pulp, cereal bran (Asther et al., 1997)	Commensalism of two micro-organisms degrading the substrate	Flavour vanillin
1994	Tomato pomace (Carvalheiro et al., 1994)	Co-cultures of *Trichoderma reesei* and *Sporotrichum* sp. are degrading cellulose and hemicellulose fraction	67% less cellulose, 73% less hemicellulose, enhanced lignin and protein content

DM — dry matter

Potential product substrate combinations

Substrate	Flavour	Micro-organism
Apple pomace, spent malt, spent hops, carrot pomace	Ethyl butyrate (pineapple), ethyl pentanoate (apple), isoamyl acetate (banana)	*C. fimbriata*
Sugar beet pulp (Asther et al., 1997; Bonnin et al., 1999; Lesage-Meessen et al., 1999)	Vanillin	*Pycnoporus cinnabarius*, *A. niger*
Ricinus oil cake (Feron et al., 2000; Ferreira et al., 2000)	γ-decalactone (peach)	*Yarrovia lipolytica*
	1-Octen-3-ol (mushroom)	*P. pulmonarius*
Castor oil cake (Laufenberg et al., 2001)	γ-decalactone, 6-pentyl-α-pyrone (nutty)	*M. suaveolens*, *T. harzianum*
Sunflower seed cake (Laufenberg et al., 2001)	γ-decalactone	*T. harzianum*
Olive press cake (Laufenberg et al., 2001)	γ-decalactone, δ-decalactone (coconut)	*P. ovale*, *Ceratocystis moniliformis*
Soybean coarse meal	Pyrazine (roast flavour)	*Bacillus subtilis*

Natural properties of vegetable waste (average) and expected product profile for carbons in wastewater treatment