Formulation Strategies to Enhance Health and Nutrional Value of Foods

Prof. Paola Pittia
Facoltà di Bioscienze e Tecnologie Agro-alimentari ed ambientali
Università di Teramo
ppittia@unite.it

Amman (Jordan)
28° April 2018

Who I am

Ass. Prof. In Food Science and Technology
Since 2003 @ University of Teramo (previously @ Univ. Udine)

Coordinator Master Degree in Food Science and Technology (international)

Vice-Rector of Internationalisation and Joint Study programmes of University of Teramo

President of ISEKI-Food Association

Research expertise

- Food quality and processing
- New product design and formulation
- Physical properties of foods

Introduction

Fresh

Food preparation /traformation/preservation

Processing/transformation

- **shelf-life (migration/wars, discoveries….)**
- **safety**
- **Improvement quality and sensory properties**

Introduction

House/home preparation

Sun/wind → *Drying*

Salt → *Salting*

Sugar → *Sugar-based preserves*

Fire/smoke → *Smoking*

Environmental microrganisms → *Fermentation*

Herbs /spices → *Seasonings*

Cooking

Salting +Drying

Salting+drying +smoking

Salting+drying +smoking+ferment ation

Curing+salting+ +Drying

Introduction

Sun/wind *Drying*

Salting +Drying

PROCESSED FOOD PRODUCTS

=

HISTORICAL/TRADITIONAL

ing

Salting+drying

+smoking+ferment

INDUSTRIAL/MODERN FOOD PRODUCTS

ting+

Ho

Introduction

Innovation in the food sector: drivers

- *Advancements in science and technology*

- Identifcation and detection of new foodborne pathogens a
- Evaluation of presence and concentration of contaminants and undesired chemicals, at nano level.
- New applied sciences (nanomaterials)

- ***Societal and economic changes***

- Globalisation (population, food, cultures)
- Change of the importance of the quality attributes as response of modern consumers' expectations.
    - Increased relevance of healthy, sensory and convenience aspects (nutritional value and food safety: intrinsic aspects).

Introduction

Innovation in the food sector: drivers

- ***Critical points of conventional products (e.g. thermal processes)***
  - Main degradation of food nutrients
  - Change quality properties (e.g. textural and physical characteristics of food products)
  - Reduced consumer acceptability.

Introduction

Negative impact of conventional processes and formulation strategies

- **Intense thermal treatments (sanitisation, drying):**
  - Degradation of thermolable biomolecules and nutrients
  - Triggering and development of thermo-induced reactions and formation of unhealthy compounds, e.g.
    - Maillard reaction: acrylamide,
    - Frying: fat oxidation compounds

- **Salting and ripening of meat and dairy products** (empiric process approach)
  - Excessive use of salt
  - Potentially toxic compounds (nitrosamines)

- **Use of sugar in fruit preserves**
  - Excessive use of sugar (energy intake, cariogenicity)

Introduction

Negative impact of conventional processes and formulation strategies

NATURALLY PRESENT

- Cholesterol
- Caffein
- Allergenic substances (mainly proteins)
- Gluten

ADDED in FORMULATED foods

- Additives
- Artificial colouring and flavouring agents
- preservatives

An «extreme» definition of processed foods

Ultra-processed food (Monteiro, 2015)
Processing of substances derived from foods (by e.g. baking, fryng, extruding, moulding, re-shaping, hydrogenation and hydrolysis. They generally include a large number of additives such as preservatives, sweeteners, sensory enhancers, colorants, flavours and processing aids, but little or no whole food. They may be fortified with micronutrients. The aim is to create durable, convenient and palatable ready-to-eat or ready-to-heat food products suitable to be consumed as snacks or to replace freshly prepared food-based dishes and meals

Monteiro, CA; Moubarac, JC; Cannon, G; Ng, SW; Popkin, B (2013). "Ultra-processed products are becoming dominant in the global food system". Obes Rev. 14 Suppl 2: 21–8.

An «extreme» definition of processed foods

Fresh = healthy

Formulated & processed = extremely unhealthy

An «extreme» definition of processed foods

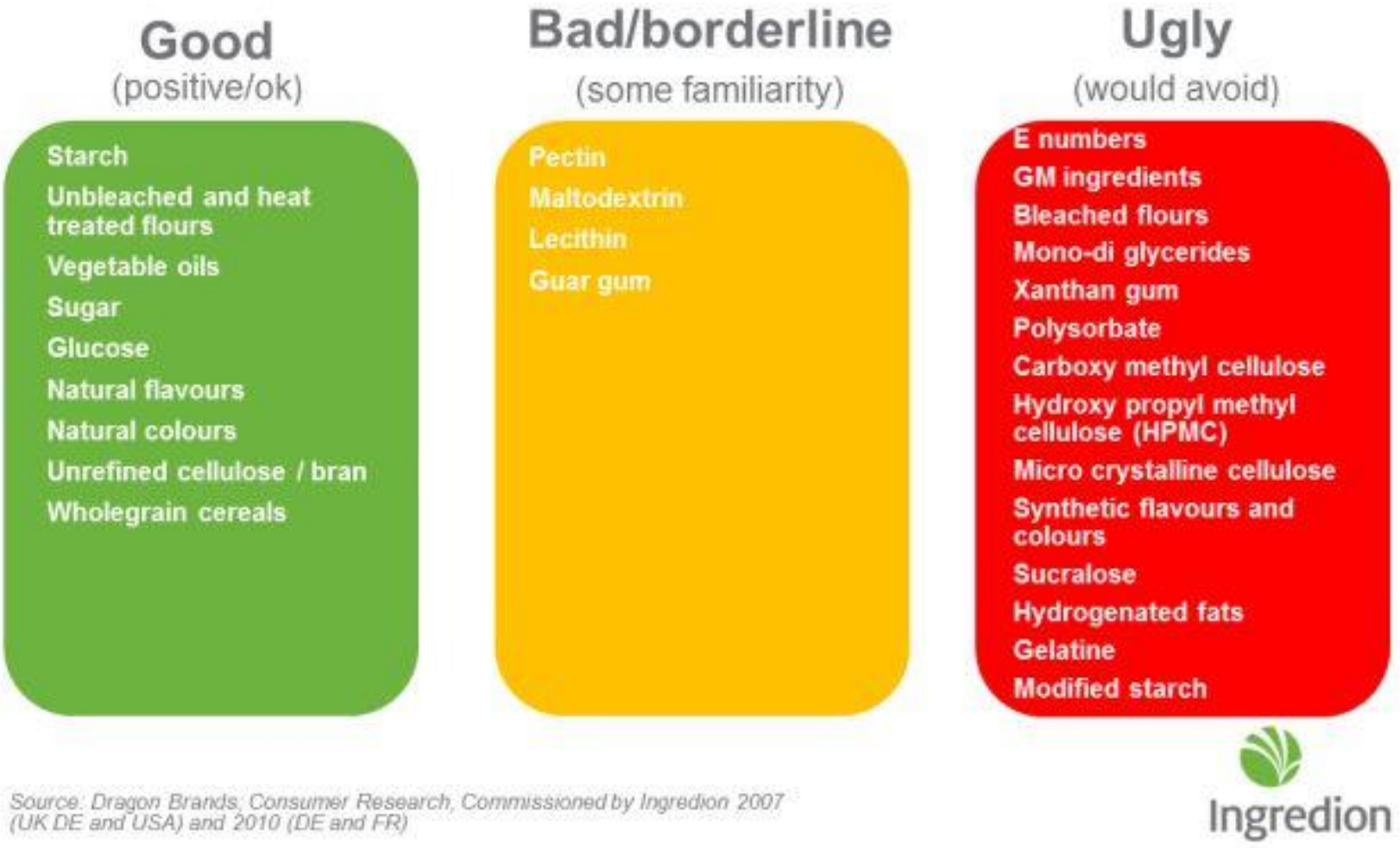
Fresh = healthy

Formulated & processed = extremely unhealthy

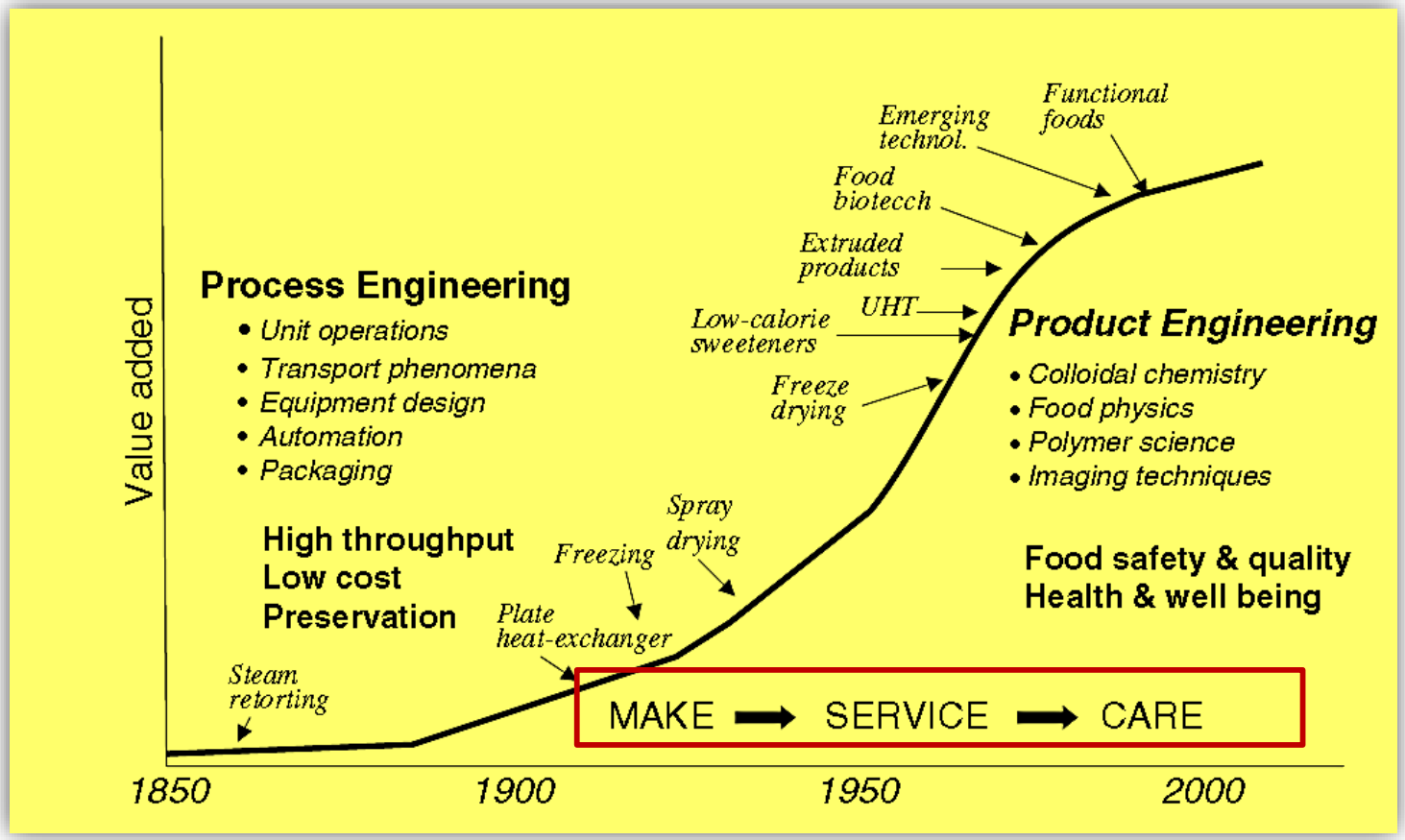
«Clean label» approach

- Few ingredients; avoid lengthy ingredient statements
- Ingredient names are recognizable; avoid unfamiliar names
- Transparency to consumers
- Absence of artificial ingredients
- Minimally processed
- Natural
- Allergen-free
- Uncluttered label

«Clean label» approach



Products and food processing evolution



Aguilera, 2006

Health and diet consumer trends

Natural & unprocessed

Nutritional balance & specific health benefits

Reduced ecological impact and fair trade

Convenience and new consumption occasions

Affordability

Balanced presence of nutrients to deliver the desired/needed energy intake

Reduction/replacement of undesired ingredients and macro-/micro-nutrients (nutrition, health aspects)

Revision of formulation
Diversification

Modified from Palzer, ICEF 12 conference 2015

Food product design

Health and diet consumer trends

Natural & unprocessed

Nutritional balance & specific health benefits

Reduced ecological impact and fair trade

Convenience and new consumption occasions

Affordability

Presence and content of health promoting compounds by
- **nature**
- **processing (conventional/innovative)**
- **processing optimisation**

Presence and content of health promoting compounds
- **fortification /enrichment**
- **formulation (mix)**

Food product design

Modified from Palzer, ICEF 12 conference 2015

Formulation strategies to enhance nutr.& health Q

- **SUGAR/mono- di-saccharides**
  (not only sweeteners….)

AIM: decrease energy intake, improve healthy potential, no-cariogenicity, low glycemic index)

CONSTRAINTS of REDUCTION/SUBSTITUTION

- need of addition of bulking agents (intensive sweeteners)
- decreased shelf-life due to lower water binding capacity of the alternative sweeteners (aw)
- effect on taste
- effect on other sensory quality (colour, aroma, texture)

Formulation strategies to enhance nutr.& health Q

- **SUGAR/mono- di-saccharides (not only sweeteners….)**

STRATEGIES: Use of alternative sweeteners (low/reduced calories, intensive)

Use of natural syrups (clean label, no/low sucrose)

Formulation strategies to enhance nutr.& health Q

- SUGAR/mono- di-saccharides
  (not only sweeteners….)

Formulation strategies to enhance nutr.& health Q

- **SALT (Sodium chloride, NaCl)**

(not only saltiness….)

AIM: decrease risk of blood deseases , ipertension)

CONSTRAINTS OF REDUCTION/SUBSTITUTION:

- decreased shelf-life due to lower water binding capacity of the alternative salting agents (aw)
- effect on taste
- effect on other sensory quality (aroma, texture)

Formulation strategies to enhance nutr.& health Q

- **SALT (Sodium chloride, NaCl)**

(not only saltiness….)

AIM: decrease risk of blood deseases , ipertension)

STRATEGIES

- Processing approaches: revision/optimisation of the conventional tecnological actions in salting, curing, fermentation process order to reduce (up to the limits) the salt applied (Martuscelli et al. 2015, 2017

- Use of alternative salting agents (single/mix e.g. KCl, aminoacids….)

- Use of mix of herbs and spices (naturally containing minerals, salts

Formulation strategies to enhance nutr.& health Q

- **PROTEINS**
  - of vegetal origin (meat proteins substitutes, meat analogues) (food for consumers with dedicated diets-vegan/vegetarians)
  - No gluten (celiac desease)

AIM: products for specific food consumers and diversification

- **Meat/egg protein alternatives**
  - Soia proteins
  - Legume proteins (peas, bean, chickpea)
  - Seeds proteins (almond, hemp)
  - …
- **New protein sources**
  - Insects!
  - Algae
  - …..

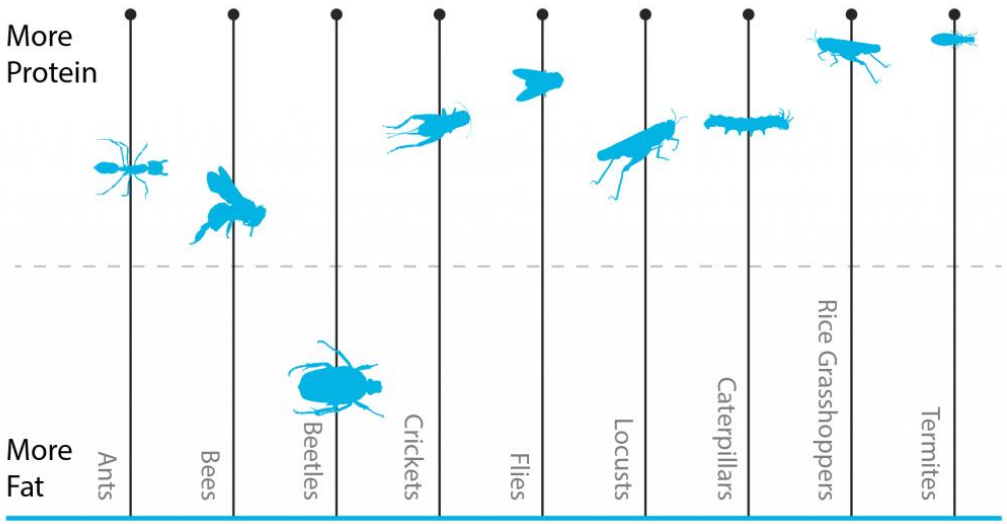
Coconut cake with cricket flour

TECHNOLOGICAL FUNCTIONALITY HAS TO BE PROPERLY TESTED UNDER THE REQUESTED USES AND FORMULATION

Formulation strategies to enhance nutr.& health Q

UNITE UNIVERSITÀ DEGLI STUDI DI TERAMO

- **PROTEINS**



Nutrition Facts

Per 100 grams of cooked weight	Mealworms	Crickets
	Roasted	**Boiled, roasted**
Calories	436	472
Protein	55.43 g	58.51 g
Fat	18.9 g	24.0 g
Saturated	4.13 g	8.48 g
Monounsaturated	6.48 g	5.14 g
Polyunsaturated	7.33 g	9.09 g
Omega-6	7.03 g	6.28 g
Omega-3	0.297 g	2.81 g
Carbohydrates	15.4 g	8.4 g
Sugars	0.5 g	0.4 g
Dietary fiber	8.7 g	6 g
Cholesterol	149 mg	228 mg
Vitamin A	620 IU	no data
Calcium	810 mcg	1100 mcg
Iron	37 mcg	25 mcg
Potassium	11 mg	11 mg
Sodium	1.8 mg	3.1 mg

Insects:
http://www.proteinsect.eu/

Formulation strategies to enhance nutr.& health Q

- **PROTEINS**

Arthospira (Spirulina) platensis : blue-green microalga (cyanobacterium) which belongs to the Lichinaceae Family.

Phycocyanin: up to **80% of the protein fraction**

Formulation strategies to enhance nutr.& health Q

- **PROTEINS**

Applications

- ***Foods*** *("colouring foodstuff", energy enhancer)*
- **Nutraceutical**
- **Cosmetics**
- **Diagnostic**, clinical assays (fluorescent probe)

Properties

Antioxidant

- Free Radical-scavenging activity
- Inibition of lipid peroxidation

Medical and Pharma

- Hepatoprotective
- Anti-inflammatory
- neuroprotective
- Immuno-system enhancer

Formulation strategies to enhance nutr.& health Q

- **GLUTEN FREE (celiac desease)**

Gluten is the proteic three dimensional elastic structure that originates during kneading of cereals containing glutein proteins (gliadins and glutenins) in presence of water.

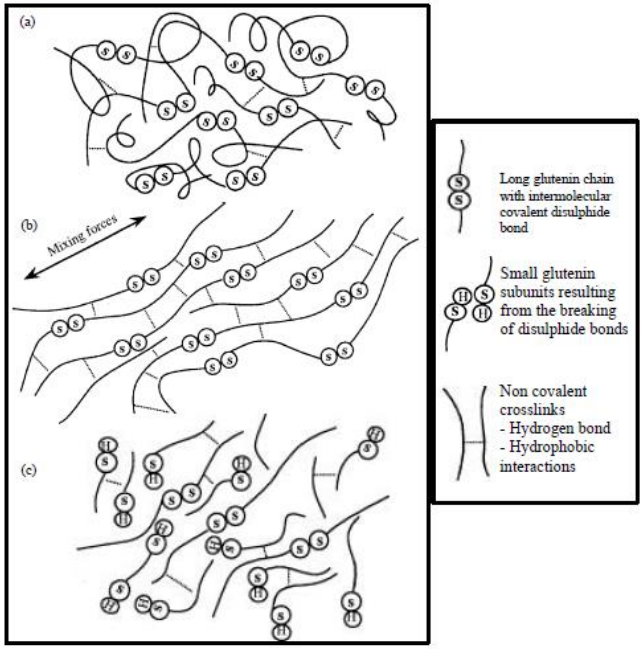


Fig. 3: Molecular interpretation of gluten development (a) beginning of mixing, (b) optimum development and (c) overmixing (Letang *et al.*, 1999)

CONSTRAINS: causes celiac desease with main health symptoms and injuries in the bowl and side-effects

Formulation strategies to enhance nutr.& health Q

- **GLUTEN FREE (celiac desease)**

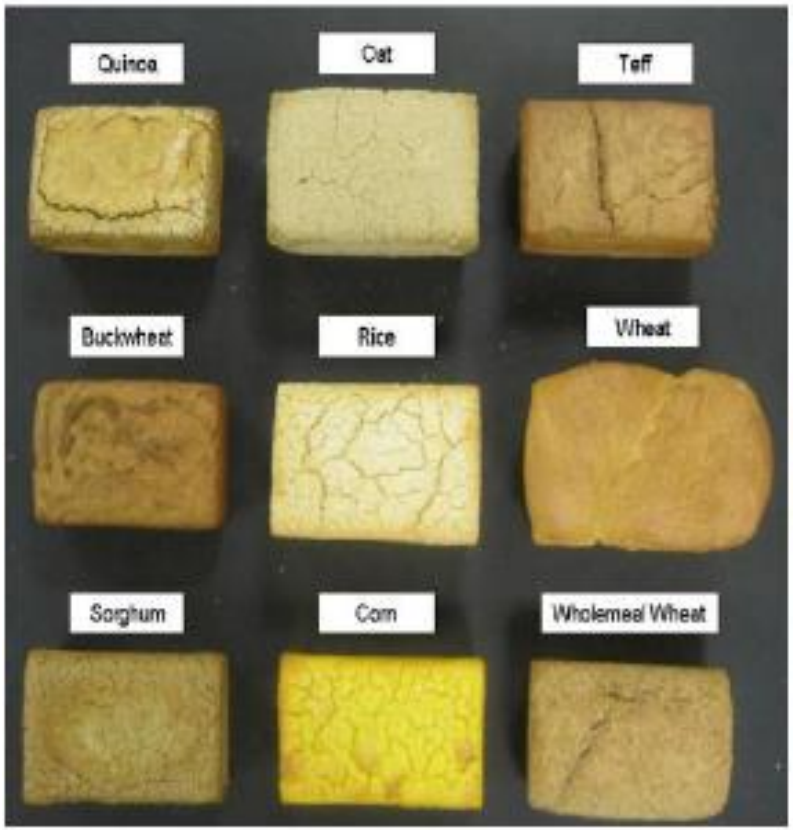
Use of pseudo-cereals, starches + able to develop a three dimensional network similar to gluten

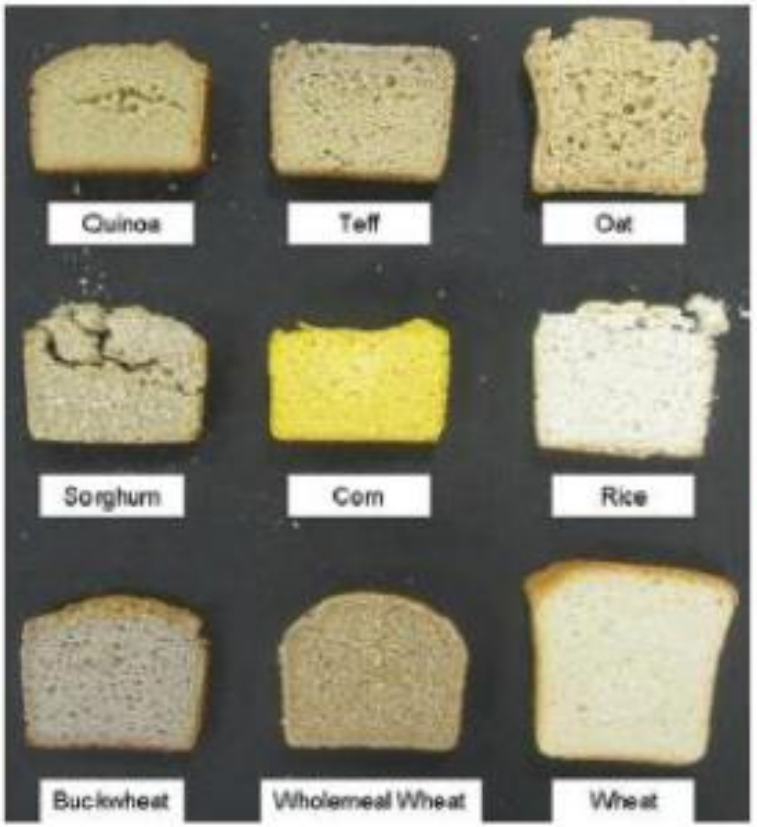
	„Standard“ cereals	„New“ (pseudo-) cereals	
Gluten free	Rice	Buckwheat	Gluten free
	Maize	Quinoa	
Not gluten free	Bread wheat, Durum, Rye, Spelt, Barley, … 	Millet	
		Sorghum	
		Teff	
		Oat	

Formulation strategies to enhance nutr.& health Q

- **GLUTEN FREE (celiac desease)**

Use of pseudo-cereals, starches + able to develop a three dimensional network similar to gluten



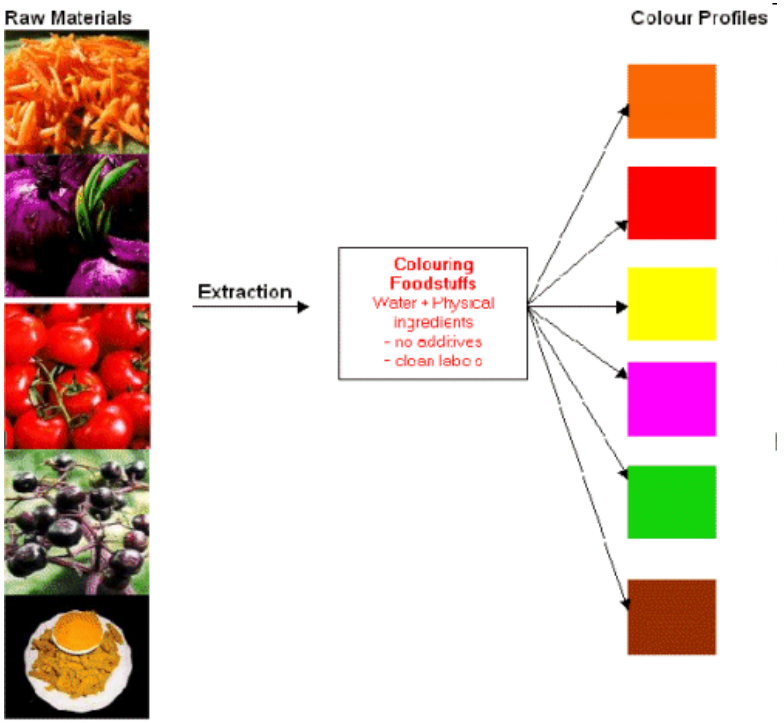


Formulation strategies to enhance nutr.& health Q

- **AROMA AND FLAVOUR**

AIM: to avoid use of E-labelled additives

STRATEGIES: Use of natural extracts (plants, fruits, vegetables, essential oils



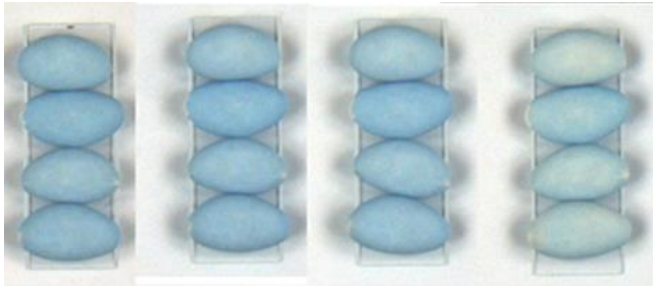
Formulation strategies to enhance nutr.& health Q

CONSTRAINTS: COLOURING EXTRACTS: poor STABILITY, with destabilisation correlated to discoloration/ bleaching

Matrix & environmental destabilising factors:

- pH
- Temperature
- Light

Temperature & light



Freshly made 10 d 20 d 60 d

Temperature & pH

Light, 60% RH

NEED OF IDENTIFICATION STABILISING PROCESSING AND FORMULATION ACTIONS TO PREVENT DISCOLORANTION/LOSS QUALITY

Formulation strategies to enhance nutr.& health Q

- **FORTIFICATION/ADDITION DESIRED COMPOUNDS**

  AIM: to enhance by formulation the nutritional and health potential of the final product

BIOMOLECOLES /COMPOUNDS OF MAIN INTEREST

- Phytochemicals
- Phenolic compounds (extracts, pure compounds)
- Minerals
- Vitamins
- Fibers
- Pre-biotics
- Probiotics
- Essential aminoacids, fatty acids
- ….

Formulation strategies to enhance nutr.& health Q

- **FORTIFICATION/ADDITION DESIRED COMPOUNDS**

BIOMOLECOLES /COMPOUNDS OF MAIN INTEREST

- Phytochemicals
- Phenolic compounds (extracts, pure compounds)
- Minerals
- Vitamins
- Fibers
- Pre-biotics
- Probiotics
- Essential aminoacids, fatty acids
- ….

NUTRITIONAL/HEALTH VALUE

TECHNOLOGICAL PROPERTIES (ES. IN COLLOIDAL SYSTEMS)

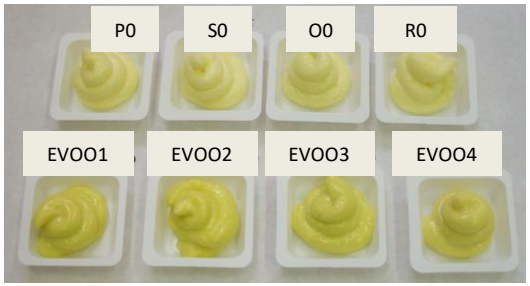
BIOACCESSIBILITY?

Formulation strategies to enhance nutr.& health Q

UNITE UNIVERSITÀ DEGLI STUDI DI TERAMO

- **FORTIFICATION/ADDITION DESIRED COMPOUNDS**

Role of phenolic compounds in emulsified systems (case study)



LWT - Food Science and Technology xxx (2014) 1–7

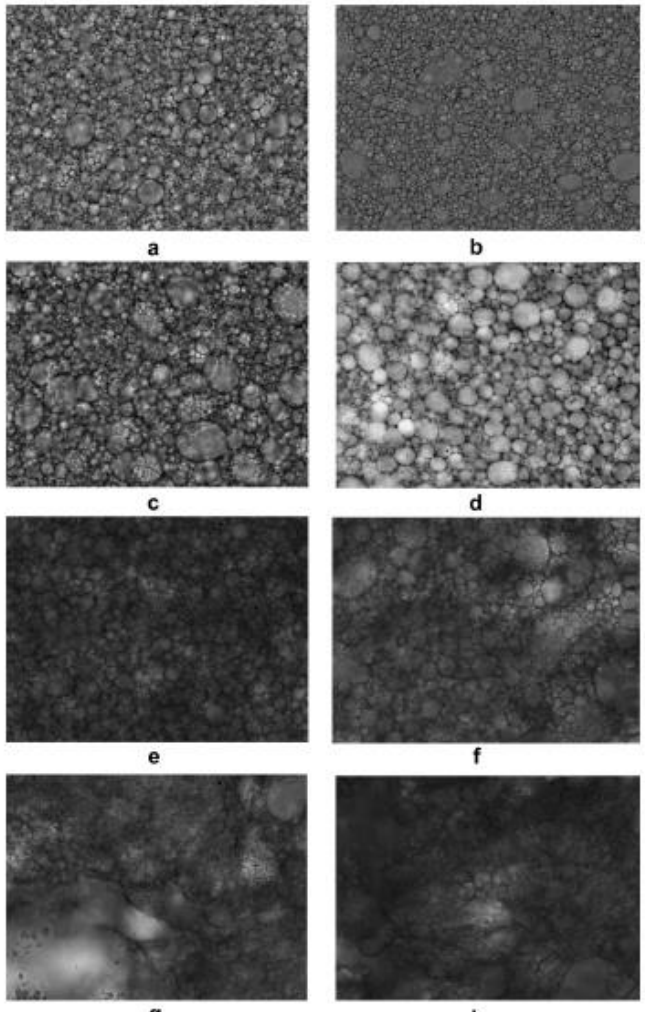
Contents lists available at ScienceDirect

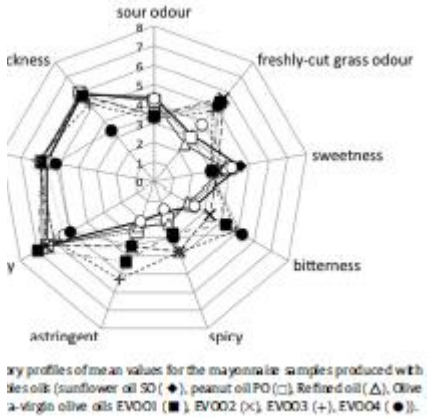
LWT - Food Science and Technology

journal homepage: www.elsevier.com/locate/lwt

Physical and structural properties of extra-virgin olive oil based mayonnaise

Carla Di Mattia [a, *], Federica Balestra [b], Giampiero Sacchetti [a], Lilia Neri [a], Dino Mastrocola [a], Paola Pittia [a]





ory profiles of mean values for the mayonnaise samples produced with ties oils (sunflower oil SO (◆), peanut oil PO (□), Refined oil (△), Olive a-virgin olive oils EVOO1 (■), EVOO2 (×), EVOO3 (+), EVOO4 (●)).

Formulation strategies to enhance nutr.& health Q

- **UNRAVEL HEALTH POTENTIAL OF NATURAL, UNDERESTIMATED SOURCES AND BY-PRODUCTS**

AIM: To add-value to biodiversity and traditional/old raw materials as healthy ingredients

To recover healthy coumpounds from waste

Valorisation of biodiversity

Contents lists available at ScienceDirect

Journal of Food Composition and Analysis

journal homepage: www.elsevier.com/locate/jfca

Original Article

Chemical composition and antioxidant activity of cured chestnuts from three sweet chestnut (*Castanea sativa* Mill.) ecotypes from Italy

L. Neri, G. Dimitri, G. Sacchetti *

Department of Food Science, University of Teramo, Via C.R. Lerici 1, 64023 Mosciano Stazione, Teramo, Italy

Table 4
Means and standard deviations of the organic acids, polyphenols concentration and antioxidant activity of chestnuts and ANOVA analysis of the effects of ecotype and harvesting year.

Ecotype	Year	Malic acid (%d.w.)	Ascorbic acid (%d.w.)	Total polyphenols (μg GAE $g^{-1}_{d.w.}$)	Antioxidant activity (μmoles Trolox eq. $g^{-1}_{d.w.}$)
VC	2003	0.224 ± 0.008	0.032 ± 0.009	87.2 ± 6.5	6.49 ± 0.19
VC	2004	0.290 ± 0.120	-	89.2 ± 7.3	5.49 ± 0.21
CDR	2003	0.330 ± 0.094	0.059 ± 0.008	133 ± 8.5	8.15 ± 0.16
CDR	2004	0.152 ± 0.002	0.028 ± 0.002	105 ± 7.6	4.77 ± 0.34
MR	2003	0.188 ± 0.005	0.078 ± 0.007	101 ± 6.2	6.00 ± 0.49
MR	2004	0.181 ± 0.004	0.128 ± 0.010	157 ± 20	5.59 ± 0.40
F	Ecotype (E)	n.s.	123.36***	24.51***	6.77*
F	Year (Y)	n.s.	n.s.	n.s.	140.75***
F	E × Y	6.05*	90.71***	24.56***	35.8***

d.w.: dry weight; n.s.: not significant. Significance level: *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

Formulation strategies to enhance nutr.& health Q

- UNRAVEL HEALTH POTENTIAL OF NATURAL, UNDERESTIMATED SOURCES AND BY-PRODUCTS

- **Apples (from autoctonous cultivars)**

International Journal of Food Science and Technology 2008, 43, 797–804

Original article

Influence of processing and storage on the antioxidant activity of apple derivatives

Giampiero Sacchetti,[1]* Emiliano Cocci,[2] GianGaetano Pinnavaia,[2] Dino Mastrocola[1] & Marco Dalla Rosa[2]

1 Dipartimento di Scienze degli Alimenti, Università degli Studi di Teramo, Via Carlo Lerici 1, Mosciano Stazione, 64023 Teramo, Italy
2 Campus di Scienze degli Alimenti, Università degli Studi di Bologna, Sede di Cesena, Piazza Goidanich 60, 47023 Cesena, Italy

Apple variety	Polyphenols (mg g^{-1} d.w.)	Ascorbic acid (mg 100 g^{-1} d.w.)	TEAC (μmol Trolox eq. g^{-1} d.w.)
Campanino	4.99 ± 0.10	16.43 ± 0.73	48.97 ± 1.35
Commercio	2.21 ± 0.67	11.56 ± 0.64	7.17 ± 0.35
Decio	3.01 ± 1.19	9.02 ± 0.75	13.30 ± 3.09
Durello	4.34 ± 0.61	12.66 ± 0.30	26.91 ± 3.67
Golden Delicious	2.65 ± 0.08	9.89 ± 0.43	15.17 ± 1.27
Puppino	5.29 ± 1.63	18.78 ± 1.17	44.20 ± 4.24
Verdone	3.95 ± 1.34	14.29 ± 0.48	35.18 ± 2.87

Table 1 Antioxidants content and Trolox equivalent antioxidant capacity (TEAC) (±S.D.) of fresh fruits

Formulation strategies to enhance nutr.& health Q

UNITE UNIVERSITÀ DEGLI STUDI DI TERAMO

- UNRAVEL HEALTH POTENTIAL OF NATURAL, UNDERESTIMATED SOURCES AND BY-PRODUCTS

- **Apples (from autoctonous cultivars)**

International Journal of Food Science and Technology 2008, **43**, 797–804

Original article

Influence of processing and storage on the antioxidant activity of apple derivatives

Giampiero Sacchetti,[1]* Emiliano Cocci,[2] GianGaetano Pinnavaia,[2] Dino Mastrocola[1] & Marco Dalla Rosa[2]

1 Dipartimento di Scienze degli Alimenti, Università degli Studi di Teramo, Via Carlo Lerici 1, Mosciano Stazione, 64023 Teramo, Italy
2 Campus di Scienze degli Alimenti, Università degli Studi di Bologna, Sede di Cesena, Piazza Goidanich 60, 47023 Cesena, Italy

	Dried cubes		Purees	
Apple variety	TEAC (μmol Trolox eq. $g^{-1}_{d.w.}$)	$\Delta h°$ (%)	TEAC (μmol Trolox eq. $g^{-1}_{d.w.}$)	$\Delta h°$ (%)
Campanino	13.80 ± 2.45	19.2 ± 0.45	11.74 ± 0.85	9.1 ± 0.73
Commercio	5.71 ± 0.43	13.2 ± 0.44	6.86 ± 0.98	18.1 ± 0.43
Decio	3.87 ± 1.12	17.9 ± 0.49	2.33 ± 0.10	15.3 ± 0.41
Durello	20.30 ± 2.03	15.7 ± 0.29	8.29 ± 1.17	9.2 ± 0.59
Golden Delicious	6.32 ± 0.37	9.9 ± 0.27	4.56 ± 0.36	–3.0 ± 0.42
Puppino	16.58 ± 4.29	12.6 ± 0.47	9.37 ± 1.04	6.0 ± 0.70
Verdone	30.01 ± 3.51	14.8 ± 0.15	8.12 ± 0.39	17.4 ± 0.24

Valorisation of biodiversity

Formulation strategies to enhance nutr.& health Q

UNITE UNIVERSITÀ DEGLI STUDI DI TERAMO

- NEW INGREDIENTS FROM ISOLATED/EXTRACTED BIOCOMPOUNDS ISOLATED

Raw materials (biodiversity, minor)

By-products

Waste

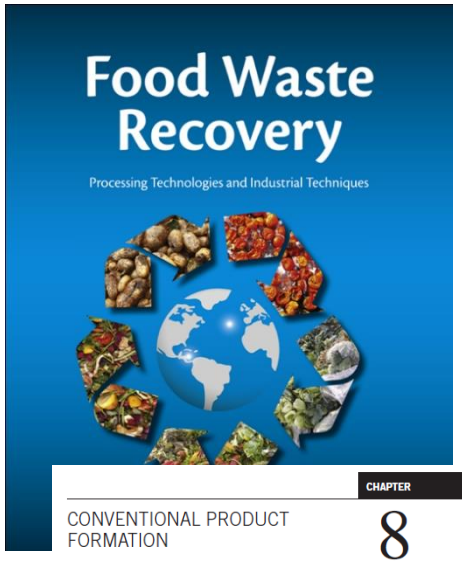


Table 8.1 General Technological Functionalities of the Main Compounds Present in Food Waste and By-Products

Compound	Origin/Source of Waste and By-Products	Solubility	Technological/Quality Functionality
Pectin	Fruit and vegetable extracts	Water	Gelling and structuring Surface activity
Proteins	Meat (animal) Milk Eggs Vegetables (legumes) Seeds	Water Amphiphilic behavior	Emulsifying and foaming activity Gelling and structuring Binding (aroma, lipids) Antioxidant properties
Peptides and amino acids	Meat (animal) Milk Vegetables Seeds	Water Amphiphilic behavior	Solubility Emulsifying and foaming activity Bioactivity Health properties
Oligosaccharides	Fruit and vegetables	Water	Solubility Healthy properties
Polysaccharides	Fruit and vegetables	Water	Water-holding and binding properties Gelling and structuring
Hydrocolloids and gums	Vegetables, seeds	Water	Gelling and structuring Water-holding capacity
Oils and fats	Animal, fish, seeds	Oil	Structure forming Binding (aroma, proteins) Sensory properties
Phenolic compounds	Plant and fruit extracts	Water-to-oil depending on chemical structure and molecular weight	Antioxidant Health properties Surface activity Sensory properties (color and taste)
Phytochemicals	Plant extracts	Water-to-oil depending on chemical structure and molecular weight Some have amphiphilic behavior	Solubility Surface activity Emulsifying properties Healthy properties
Pigments	Plant and fruit extracts Algae and seaweeds extracts Meat (mycoglobin)	Water-to-oil depending on the compound	Color and sensory properties
Aroma compounds and essential oils	Plant and fruit extracts	Water-to-oil depending on the compound	Aroma and sensory properties

Formulation strategies to enhance nutr.& health Q

UNITE UNIVERSITÀ DEGLI STUDI DI TERAMO

Isolation of compounds of interest

Raw materials (biodiversity, minor)

By-products

Waste

Conventional/innovative processes to produce new ingredients/additives

Extraction, emulsions, drying

PROTECTION/
SHELF-LIFE
CONTROLLED RELEASE

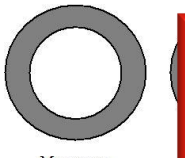


FIGURE 8.2 Microencapsulation of Lipophilic Food Ingredients by Spray Drying

Formulation strategies to enhance nutr.& health Q

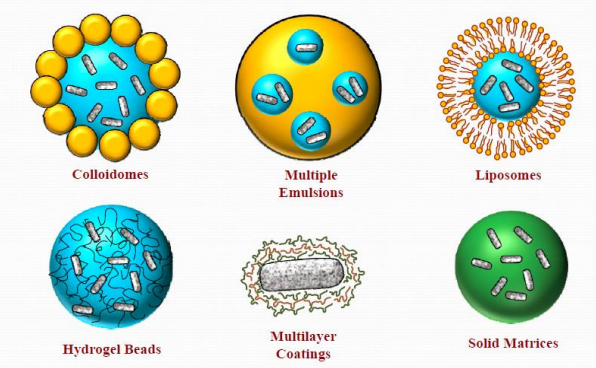
UNITE UNIVERSITÀ DEGLI STUDI DI TERAMO

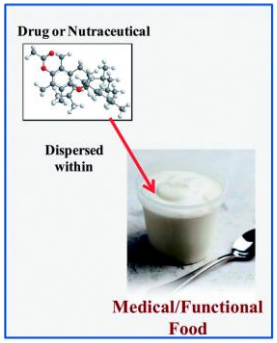
Isolation of compounds of interest

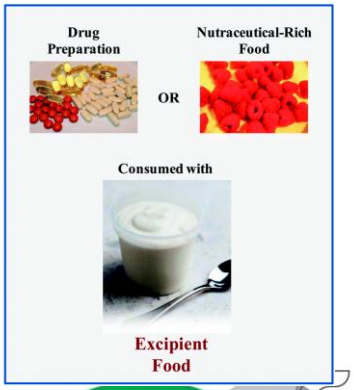
- Raw materials (biodiversity, minor)
- By-products
- Waste

Conventional/innovative processes to produce new ingredients/additives

Micro/nano encapsulation







Innovation, quality and stability issues

Any change/action on processing and formulation of a beverage requires an optimisation step to identify factors affecting its expected quality, safety and stability.

Stability

- microbial
- enzymatic
- physical (e.g. colloidal)
- chemical (e.g. oxidation)

Innovation, quality and stability issues

Any change/action on processing and formulation of a food requires an optimisation step to identify factors affecting its expected quality and stability.

Formulation

- ***selection ingredients and additives***
- ***recipe/formulation***

Processing main factors:

- ***Technological parameters***
- ***Formulation properties***
  - ***pH (high, low acidity)***
  - ***Ingredients (nutrients, natural/added antioxidants….)***
  - ***expected shelf-life (stability: microbial, enzymatic, …)***

Conclusions

Thank you very much…

Any Question?

Paola Pittia
ppittia@unite.it