# Sustainable use of fruit and vegetable by-products as new food ingredients: the case of fortified cereal-based products

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The food-processing industry produces large volumes of wastes, both solids and liquids. They are generated from the production, preparation, and consumption of food. These wastes cause potentially serious disposal and pollution problems and represent a loss of valuable biomass and nutrients.

By-products (solid and liquid form) are the secondary products generated during manufacturing of primary products (ex. olive oil, wine, juice, jelly, jam etc.).

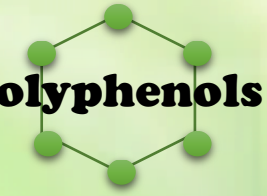

Generate

**Fruits and vegetables by-products**

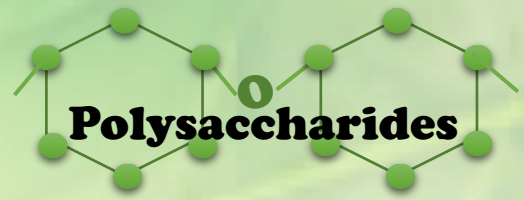
**10 - 60 %**





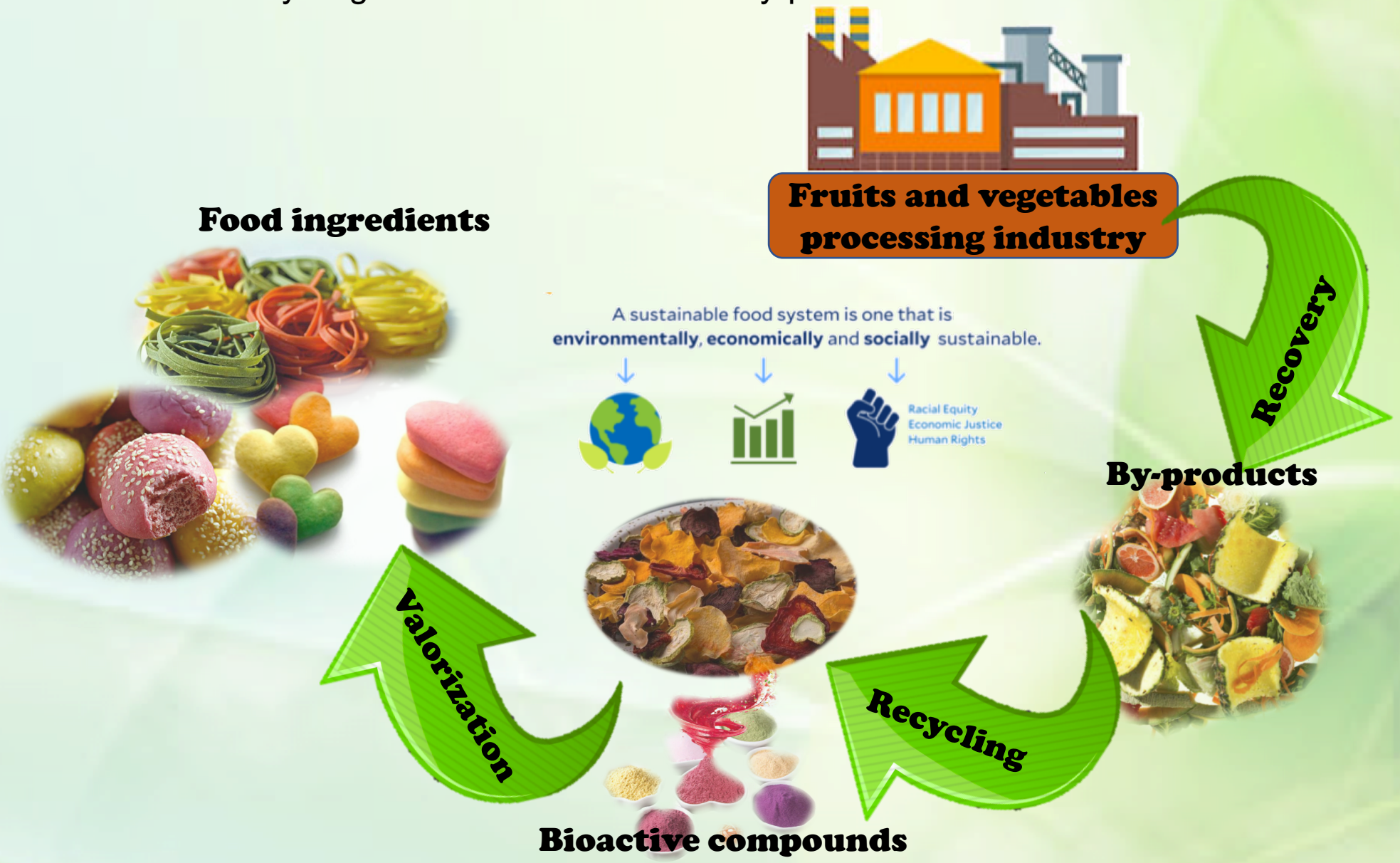





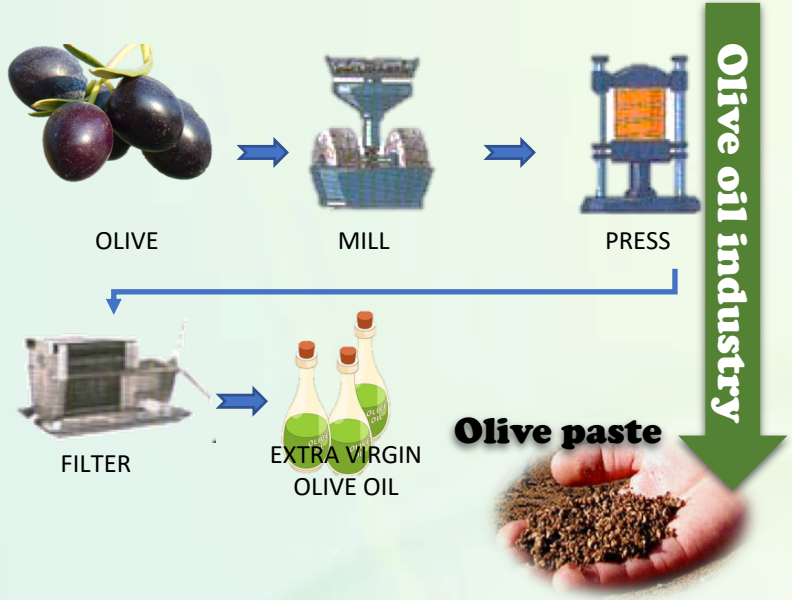



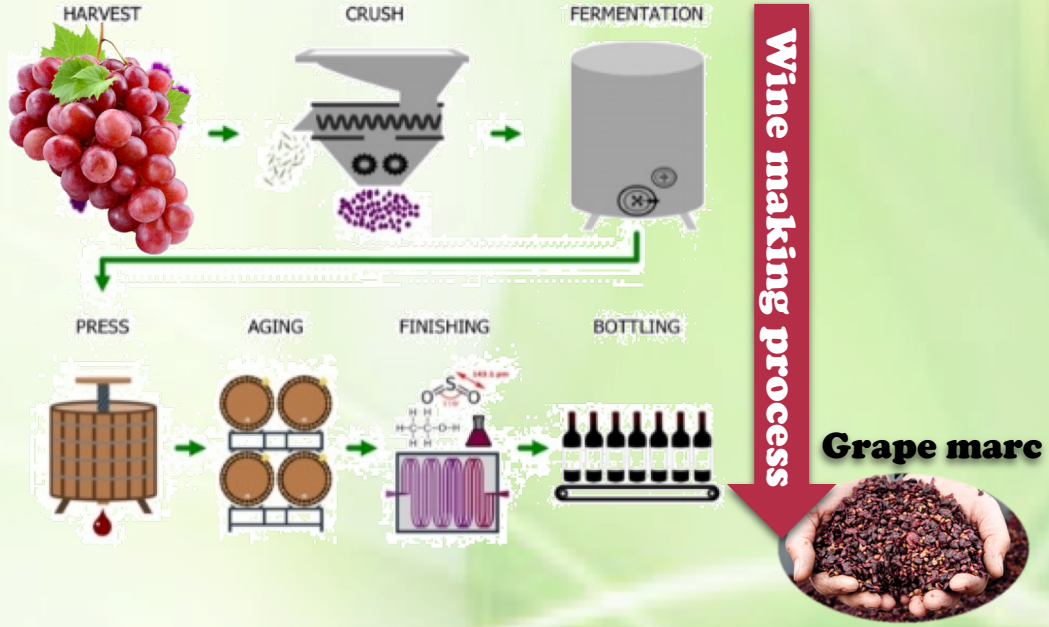

These by-products have a huge potential, because are natural source of bioactive compounds.

Among the various strategies proposed to promote the development of a sustainable food system, the recovery, recycling and valorization of food by-products is one of them.



**Objective: Evaluation of the potential application of olive paste, grape marc and tomatoes peel to cereal products formulation.**





Cereal products, for their high daily consumption are excellent carriers of bioactive substances. In particular, pasta and bread represent the best examples because they are one of the most well-known products all over the world.

# Alternative use of by-products

Wine making process

Red grape marc (RGM)

Olive oil industry

Olive paste (OP)

Tomatoes industry

Tomato Peel (TP)


## materials and methods

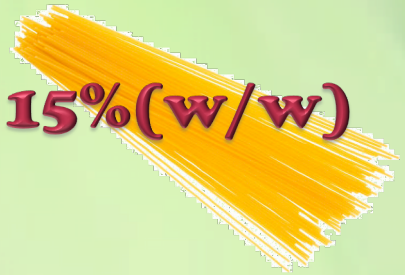
Flours were used as ingredients to formulate enriched spaghetti or bread.

Dryer

Dried and milled

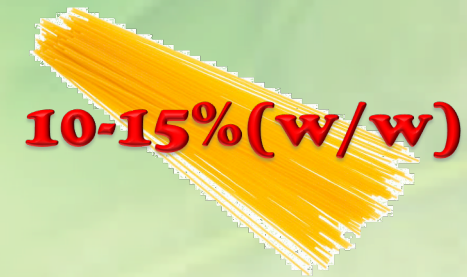
The by-products were dried at low temperature (38-40°C for 48 h) and milled to obtain the flours

RGM flour




OP flour

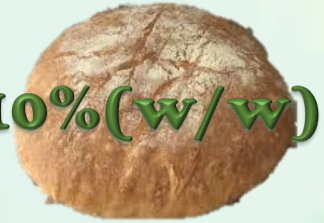

TP flour



# Alternative use of by-products

15%(w/w)

Fine RGM flour



10%(w/w)

Fine DOP flour

10-15%(w/w)

Fine TP flour

## Second Step

## materials and methods

### Extraction

- Bioactive compounds with acidified methanol (80% MeOH in $H_2O$ with 1% HCl)

### Determination

- Total polyphenols by UV-Vis spectrophotometry (Folin-Ciocalteu method).
- The antioxidant activities by FRAP assay or ABTS method
- Total flavonoids content by aluminum chloride colorimetric method, the total Anthocyanins by spectrophotometric methods, Lycopene and β-carotene contents according to Fish et al. (2002)
- Chemical composition: protein content (micro-Kjeldal method) and total dietary fiber (kit Megazyme)

### Polyphenol bio-accessibility by *in-vitro* digestion

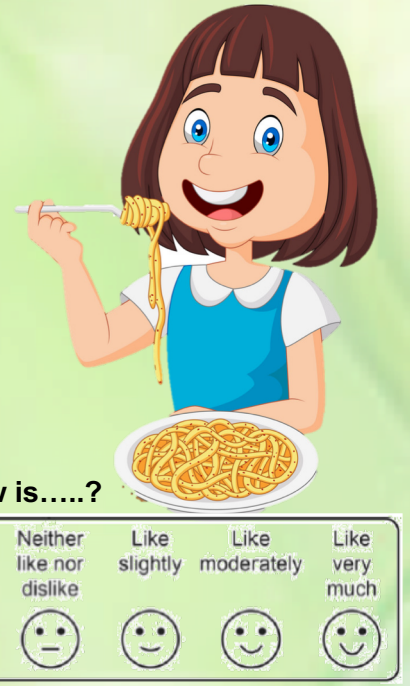
- Three stage: Oral, gastric and small intestinal phase (D'Antuono et al., 2016)

### Evaluation

- The sensory quality by a trained panel
- The glycemic response (glucose assay kit) or Glycemic index (Padalino et al., 2015)


- D'Antuono, I., Garbetta, A., Ciasca, B., Linsalata, V., Minervini, F., Lattanzio, V. M. T., Logrieco, A. F., and Cardinali, A. 2016. "Biophenols from Table Olive cv Bella di Cerignola: Chemical Characterization, Bioaccessibility, and Intestinal Absorption." *J. Agric. Food Chem.* 64 (28): 5671-8.
- Padalino, L., Conte, A., Lecce, L., Dikyova, D., and Sicari, V. 2015. "Durum Wheat Whole-Meal Spaghetti with Tomato Peel: How By-Products Particles Size Can Affect Final Quality of Pasta." J. Food Process Technol. 6 (1): 500-23.
- Fish W.W., Perkins-Veazie P., Collins J.K.A. (2002): Quantitative assay for lycopene that utilizes reduced volumes of organic solvents. J. Food Compos. Anal, 15: 309–317.

# Sensory Characteristics of uncooked and cooked spaghetti


| Uncooked Spaghetti | | | | |
|---|---|---|---|---|
| | Color | Homogeneity | Break resistance | Overall Quality |
| Ctrl | 7.30±0.21 | 7.25±0.25 | 7.20±0.21 | 7.50±0.23 |
| **RGM-125/TG** | **6.30±0.25** | **6.30±0.27** | **5.80±0.25** | **6.20±0.25** |

| Cooked Spaghetti | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Elasticity | Firmness | Adhesiveness | Color | Odor | Taste | Overall Quality |
| Ctrl | 7.50±0.21 | 7.20±0.24 | 7.40±0.24 | 7.52±0.29 | 7.80±0.28 | 7.70±0.27 | 7.30±0.30 |
| **RGM-125/TG** | **5.75±0.25** | **6.00±0.29** | **5.96±0.30** | **6.20±0.27** | **6.25±0.27** | **6.50±0.25** | **6.00±0.27** |

The spaghetti were evaluated by 10 trained panelists. CTRL: control spaghetti; RGM-125/TG: spaghetti made from 125 μm red grape marc flour (15 % w/w) and 0.6 % (w/w) transglutaminase.

The enriched samples (uncooked and cooked spaghetti) were well accepted by panelist (sensory scores equal to or greater than 6). The slight decrease in the overall quality in terms of elasticity and adhesiveness, could be explained by the formation of a not very stable network able to bind the starch granules.

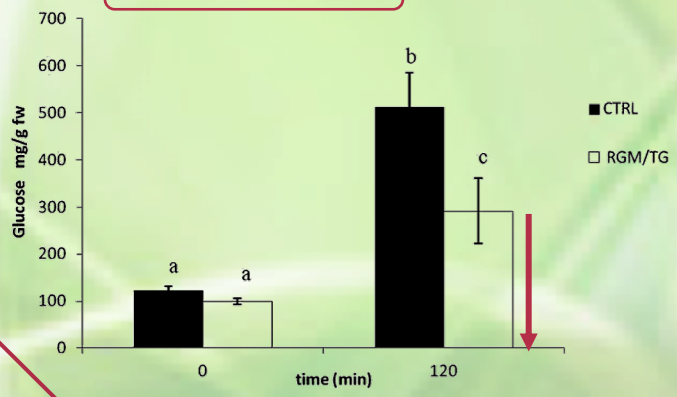
# Total polyphenols content and antioxidant activity of Ctrl and enriched spaghetti before and after cooking


| | Uncooked Spaghetti | | Cooked Spaghetti | |
|---|---|---|---|---|
| | Ctrl | RGM-125/TG | Ctrl | RGM-125/TG |
| Total polyphenols (mgGAEs/g dw) | 0.54±0.08 | 2.27±0.20 | 0.28±0.0.2 | 2.11±0.15 |
| Antioxidant activity (µmol Fe(II)/g dw) | 3.13±0.33 | 54.53±7.67 | 2.75±0.05 | 56.19±9.67 |
| Total Anthocyanins (mg mvd-glu/g dw) | ND | 0.95±0.008 | ND | 0.084±0.002 |

**RGM-125/TG**

| Bioaccessible fraction |
|---|
| 5.53±0.61 |
| 25.30±4.89 |
| 0.037±0.001 |

*In-vitro* digestion




Lower than the cooked, because the anthocyanins are partly destroyed under physiological pH during the digestion

ND: not detectable . CTRL: control spaghetti; RGM-125/TG: spaghetti containing red grape marc flour (15 % w/w; particle size ≤ 125 µm) and 0.6 % (w/w) transglutaminase; GAEs: gallic acid equivalents. Antioxidant activity (FRAP)- expressed as µmol FeSO4* 7H2O/ g dry weight (dw). Total Anthocyanins: expressed as mg malvidin 3-O-glucoside/g of dry weight (dw). Results are expressed as means ± SD, *n* = 3.

The substitution of semolina in spaghetti by red grape marc (15% w/w) increased the total polyphenols, anthocyanin content and antioxidant activity (high amount in the bio-accessible fraction). These nutritional parameters were not affected by cooking. The positive effect of the spaghetti fortification was also the decrease of bio-accessible glucose release during the *in-vitro* digestion.

# Sensory Characteristics of Ctrl and enriched bread



| Bread | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Color** | **Odor** | **Taste** | **Crust firmness** | **Crumb firmness** | **Large bubbles** | **Overall Quality** |
| **B-Ctrl** | 8.00±0.00 | 8.00±0.00 | 7.75±0.29 | 7.50±0.00 | 7.50±0.00 | 7.00±0.00 | 7.75±0.27 |
| **B-DOPF** | **6.55±0.27** | **7.75±0.27** | **6.75±0.27** | **7.50±0.00** | **7.50±0.00** | **6.68±0.24** | **7.00±0.32** |

The bread were evaluated by 6 trained panelists. B-Ctrl: bread without OP; B-DOPF: Bread made with dry olive paste flour (10 % w/w).

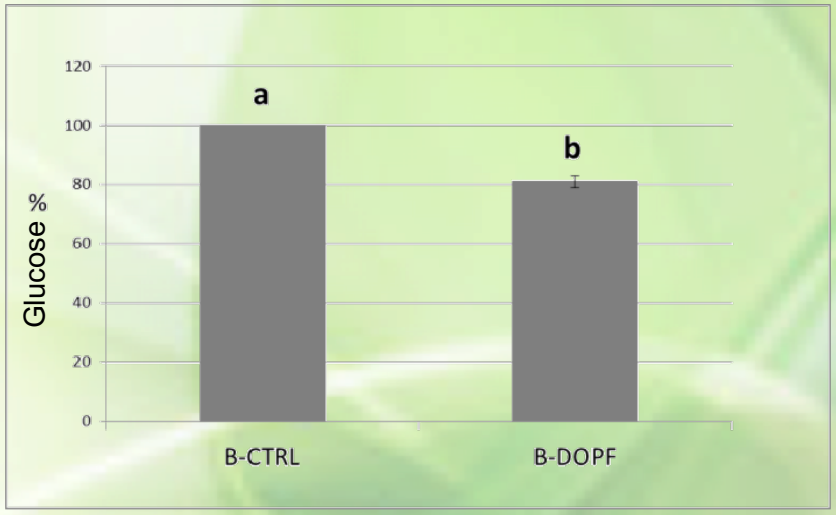
The enriched bread recorded great score. In terms of color and taste were highlighted some difference compared to the Ctrl, due to the purplish color of the by-products and the high content of polyphenols. The addition of OP flour slightly interfered with the network formation, as well visible in the bread bubbles parameter (slightly lower score than the Ctrl).

# Total polyphenols, total flavonoids and antioxidant activity of the Ctrl and the enriched bread


| Bread | | | |
|---|---|---|---|
| | **Total polyphenols (mg GAEs/g dw)** | **Total Flavonoids (mg QE/g dw)** | **Antioxidant activity (mg Trolox eq/g dw)** |
| **B-Ctrl** | 0.28±0.01 | 0.06±0.01 | 0.02±0.01 |
| **B-DOPF** | **1.96±0.04** | **0.85±0.03** | **1.12±0.02** |

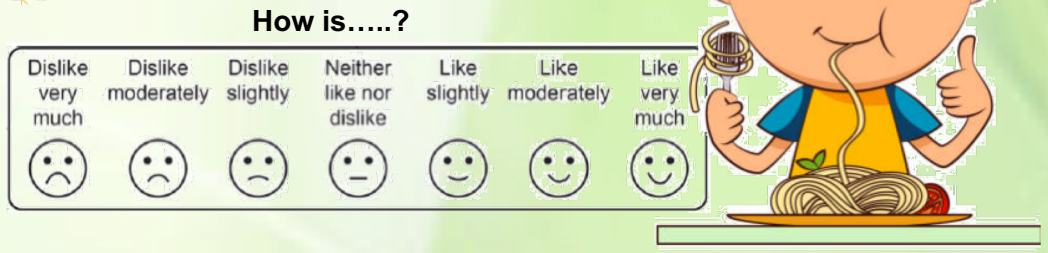
B-Ctrl: bread without OP; B-DOPF: Bread made with dry olive paste flour (10 % w/w).
GAE: gallic acid equivalents; QE: quercetin equivalent; Antioxidant activity (ABTS).
Results are expressed as means ± SD, *n* = 3.

*Glycemic index*




The bread fortified with olive paste (10% w/w) recorded high phenolic compounds, total flavonoids and antioxidant activity. The total polyphenols are stable under gastric and small-intestinal digestive conditions (Bio-accessibility 59.3% for the B-Ctrl and 72.1% for the B-OP). In addition, the glycemic index is lower than Ctrl, as the olive paste enriches the bread in fiber.

# Sensory characteristics of uncooked and cooked spaghetti

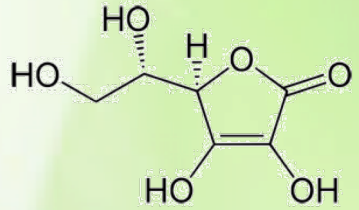

| Uncooked Spaghetti | | | |
|---|---|---|---|
| | **Color** | **Break resistance** | **Overall Quality** |
| Ctrl | 7.00±0.21 | 6.20±0.30 | 7.08±0.30 |
| 10% TP | 5.70±0.35 | 5.35±0.30 | 5.30±0.30 |
| **15% TP** | **5.27±0.36** | **4.50±0.36** | **5.00±0.47** |

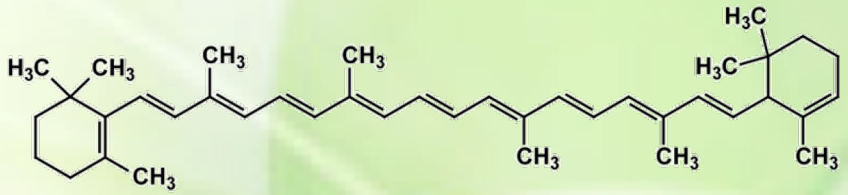
| Cooked Spaghetti | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Elasticity** | **Firmness** | **Adhesiveness** | **Color** | **Odor** | **Taste** | **Overall Quality** |
| Ctrl | 7.06±0.30 | 7.00±0.24 | 6.40±0.34 | 7.06±0.21 | 7.00±0.28 | 7.04±0.27 | 7.05±0.24 |
| 10% TP | 5.00±0.30 | 5.70±0.36 | 6.07±0.37 | 6.05±0.33 | 6.90±0.28 | 6.91±0.44 | 5.77±0.42 |
| **15% TP** | **3.88±0.30** | **5.25±0.26** | **5.20±0.31** | **5.96±0.36** | **6.86±0.26** | **6.20±0.26** | **4.38±0.38** |

The spaghetti were evaluated by 15 trained panelists. CTRL: control spaghetti; 10%TP: spaghetti made with tomato peel flour (10 % w/w); 15%TP: spaghetti made with tomato peel flour (15 % w/w)

15% peels influenced the spaghetti acceptability, due to the lower elasticity and the higher firmness compared to Ctrl. The incorporation of tomato peel flour had an impact on the fibrous nature of spaghetti, most probably for the high fiber content in the peels.

# Chemical composition of the Ctrl and the enriched spaghetti


| Chemical composition | | | | |
|---|---|---|---|---|
| | **Protein (%)** | **TDF (%)** | **Lycopene** | **β-carotene** |
| Ctrl | 15.85±0.04 | 12.83±0.17 | 0.03±0.00 | 4.04±0.08 |
| 10% TP | 10.35±0.12 | 16.80±0.23 | 0.62±0.03 | 5.16±0.06 |
| **15% TP** | **10.29±0.18** | **19.75±0.50** | **1.12±0.07** | **13.36±0.03** |

Chemical composition of dry spaghetti TDF: total dietary fiber; Carotenoids content (mg/100 g spaghetti)

The incorporation of tomato peels increased the content of carotenoids (lycopene and β-carotene) and the total dietary fiber in spaghetti samples as compared to the CTRL sample.

# CONCLUSION

- The olive oil, wine and tomato industry by-products are source of bioactive compounds and therefore can be re-utilized as functional ingredients to develop novel foods.
- The development of novel foods is a challenge, as it must meet the consumer's expectations, not only in terms of sustainability but also in terms of palatability and healthiness.
- Using by-products such as powders rather than extracts requires less processing, which is a more sustainable approach as it consumes less energy and generates no secondary by-products.
- Using by-products in form of powder requires higher doses to reach significant levels of polyphenolic fortification, which could compromise the sensory properties of the products.

# THANK YOU FOR YOUR ATTENTION

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