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## INTRODUCTION

In recent years, food research is focused on the potential of recycling fruit and vegetable by-products to reduce food waste. The by-products contain valuable compounds, especially phenolic substances, and therefore can be used to fortify food or to prolong the shelf life. In the context of food sustainability, several researches have been conducted with the aim to valorize industrial by-products. However, further efforts are necessary to make by-products available for food industry.

The aim of the study was to develop ready-to-cook breaded cod sticks by implementing new and effective combinations of by-products and fish. Both by-products were adopted as breading of ready-to-cook cod sticks.

Two case studies:

cod sticks breaded with dried olive paste as by-products of the oil production process

cod sticks breaded with pomegranate peel powder as fruit by-products

## MATERIAL AND METHODS

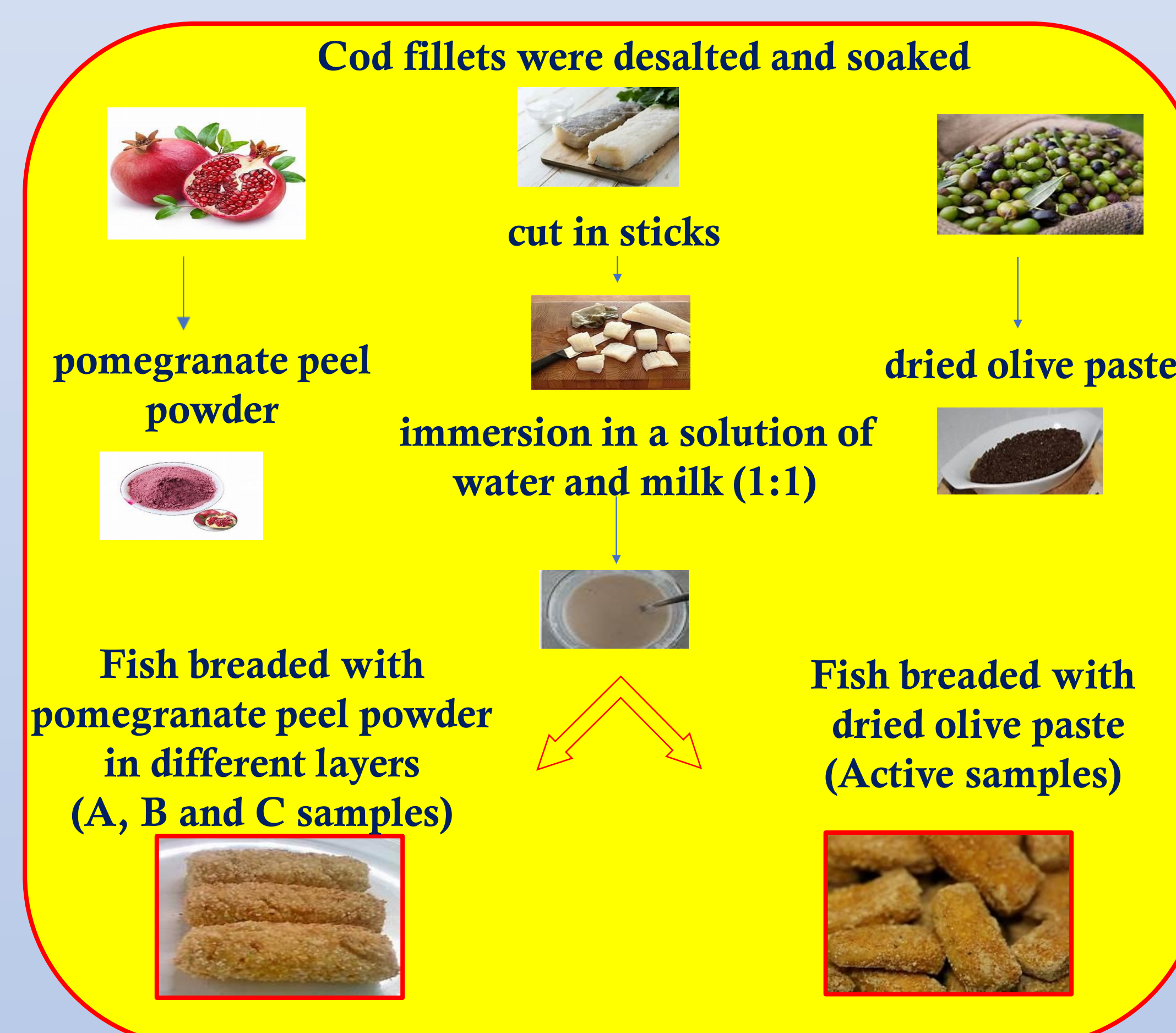
### Microbiological analyses and pH determination

Serial dilutions of control and breaded fish samples were plated onto specific media in Petri dishes to enumerate *Pseudomonas* spp., hydrogen sulfide-producing bacteria (HSPB), psychrotolerant and heat labile aerobic bacteria (PHAB), mesophilic and psychrotrophic bacteria, *Enterobacteriaceae* and lactic acid bacteria, during proper storage period under refrigerated conditions (4 °C). The measurement of pH was performed on the first homogenized dilution of samples. Analyses were carried out in duplicate on two different samples.

### Chemical analysis

Chemical analysis were conducted to determinate Total Phenol content, Total Flavonoids and Antioxidant Activity, according to standard methods. All analyses were carried out the day after sample preparation, in triplicate.

### Breaded Cod Sticks



### Sensory analyses

Five panelists were asked to give judge on odor, color, appearance, texture and overall quality using a nine-point scale. In the scale, 9 = excellent, 8 = very good, 7 = good, 6 = reasonable, 5 = not good (acceptable limit), 4 = disliked, 3 = bad, 2 = very bad and 1 = completely unacceptable.

### Statistical analyses

Experimental data of cod sticks breaded with dried olive paste were fitted by the modified version of the Gompertz equation. The experimental data of cod sticks breaded with pomegranate peel powder were compared by a one-way analysis of variance (ANOVA). A Duncan's multiple range test, with the option of homogeneous groups ( $P < 0.05$ ), was carried out to determine significant differences among samples. STATISTICA 7.1 for Windows (StatSoft, Inc, Tulsa, OK, USA) was used.

## RESULTS AND DISCUSSION

Table 1. Cod sticks with dried olive paste

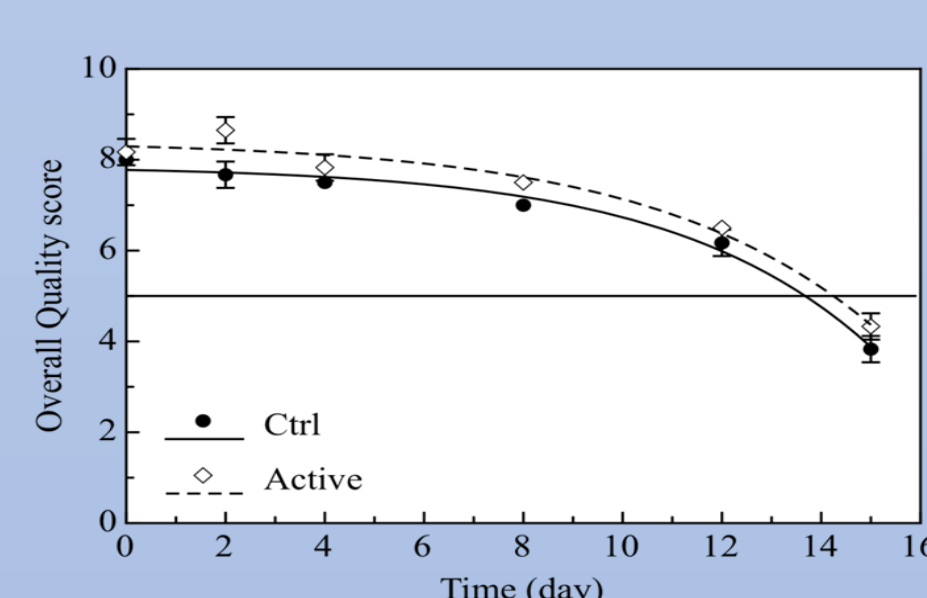
Samples	Total phenols (mg GAE/g dw) ± SD	Total flavonoids (mg QE/g dw) ± SD	Antioxidant Activity (mg Trolox/g dw) ± SD
R-Ctrl	2.70 ± 0.15 <sup>A</sup>	1.69 ± 0.09 <sup>A</sup>	5.88 ± 0.18 <sup>A</sup>
R-Active	12.63 ± 0.18 <sup>A</sup>	13.68 ± 0.90 <sup>A</sup>	20.02 ± 0.43 <sup>A</sup>
C-Ctrl	2.82 ± 0.13 <sup>A</sup>	1.38 ± 0.13 <sup>AB</sup>	4.40 ± 0.15 <sup>B</sup>
C-Active	12.46 ± 0.26 <sup>A</sup>	10.61 ± 0.53 <sup>B</sup>	12.55 ± 0.75 <sup>B</sup>

Table 2. Cod sticks with pomegranate peel powder

Samples	Total Phenols (mg GAE/g dw) ± SD	Total Flavonoids (mg QE/g dw) ± SD	Antioxidant Activity (mg Trolox/g dw) ± SD
R-Ctrl	1.17 ± 0.03 <sup>AB</sup>	0.54 ± 0.10 <sup>AB</sup>	1.05 ± 0.34 <sup>AB</sup>
R-A	8.13 ± 0.74 <sup>AB</sup>	5.43 ± 0.55 <sup>AB</sup>	5.15 ± 0.12 <sup>AB</sup>
R-B	8.44 ± 2.05 <sup>AB</sup>	5.80 ± 1.53 <sup>AB</sup>	5.47 ± 0.49 <sup>AB</sup>
R-C	10.59 ± 2.89 <sup>AB</sup>	7.19 ± 2.11 <sup>AB</sup>	7.46 ± 2.18 <sup>AB</sup>
C-Ctrl	1.24 ± 0.12 <sup>AB</sup>	0.74 ± 0.35 <sup>AB</sup>	1.08 ± 0.19 <sup>AB</sup>
C-A	5.08 ± 2.31 <sup>AB</sup>	2.87 ± 0.77 <sup>AB</sup>	2.89 ± 0.67 <sup>AB</sup>
C-B	4.19 ± 0.72 <sup>AB</sup>	1.66 ± 0.58 <sup>AB</sup>	2.19 ± 0.94 <sup>AB</sup>
C-C	6.19 ± 2.18 <sup>AB</sup>	5.8 ± 0.81 <sup>AB</sup>	4.54 ± 0.96 <sup>AB</sup>

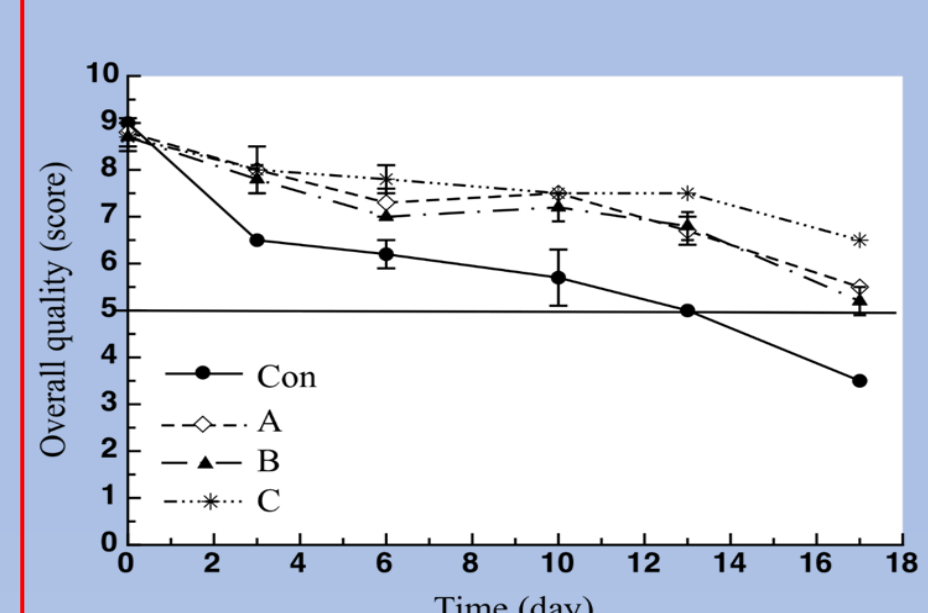
Improved nutritional quality of both raw [R] and cooked [C] fresh breaded cod sticks. Ctrl = control fish; Active = fish breaded with dried olive paste; A, B and C = fish breaded with pomegranate peel powder.

Figure 1. Overall quality of cod sticks with olive paste



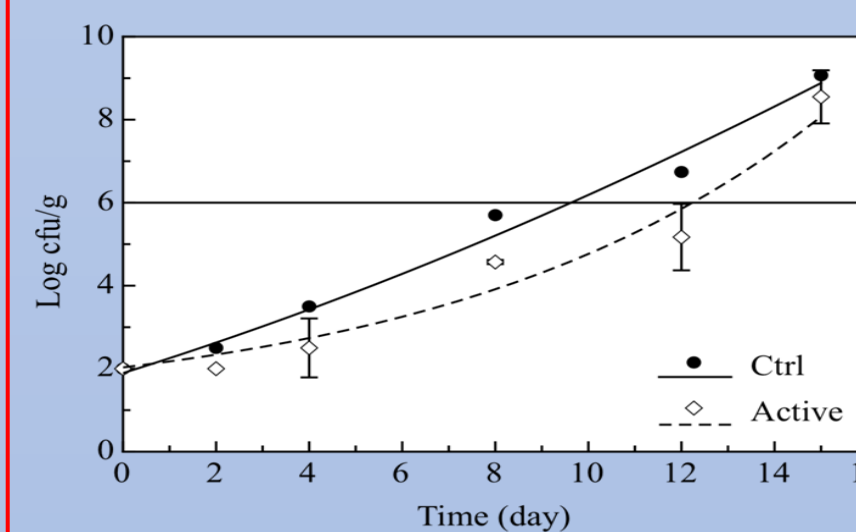
The addition of olive paste to the breading contributes to the maintenance of sensory quality.

Figure 2. Overall quality of cod sticks with pomegranate peel powder



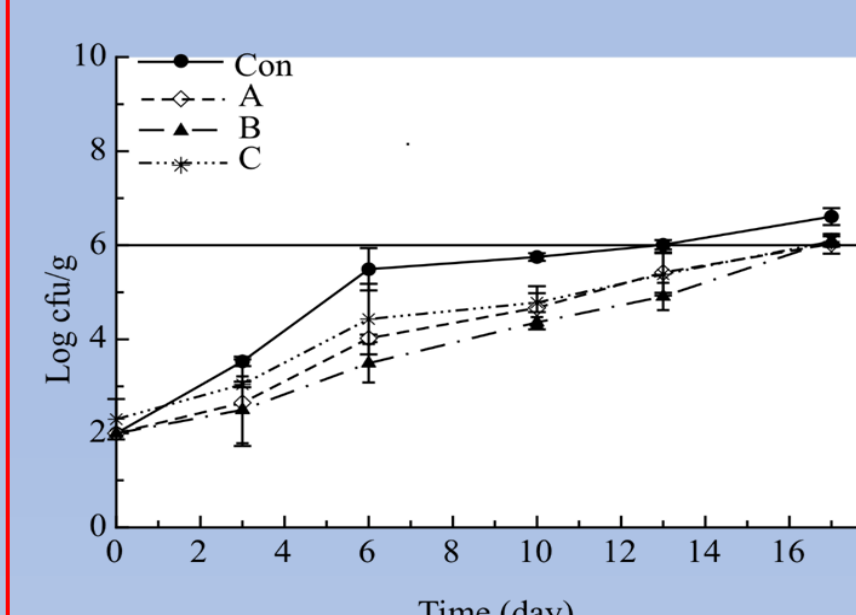
The control (Con) sample reached the threshold after 11 days, while the overall quality of all active samples (A, B and C) remained acceptable.

Figure 3. *Pseudomonas* spp. in cod sticks with olive paste



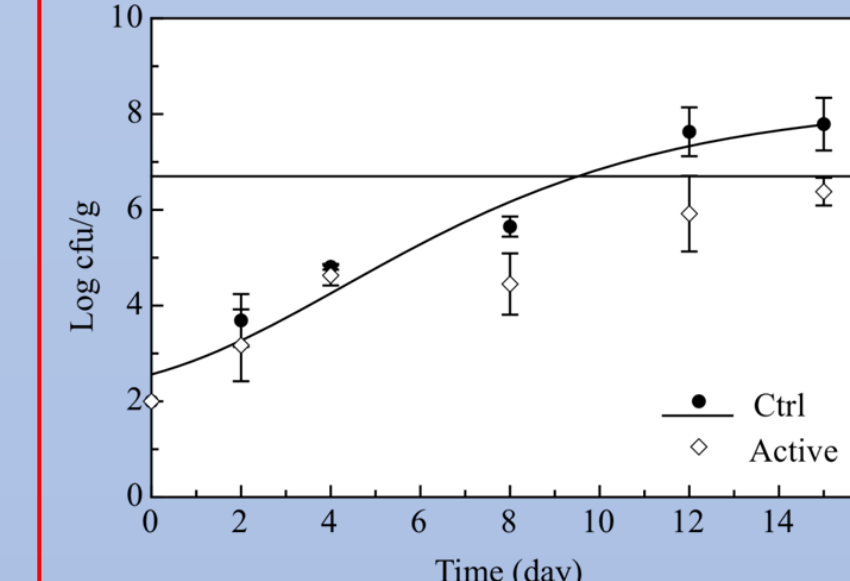
*Pseudomonas* spp. growth was slower in the active sample than in the control (Ctrl) fish, due to the active olive paste used as fish breading.

Figure 4. *Pseudomonas* spp in cod sticks with pomegranate peel powder



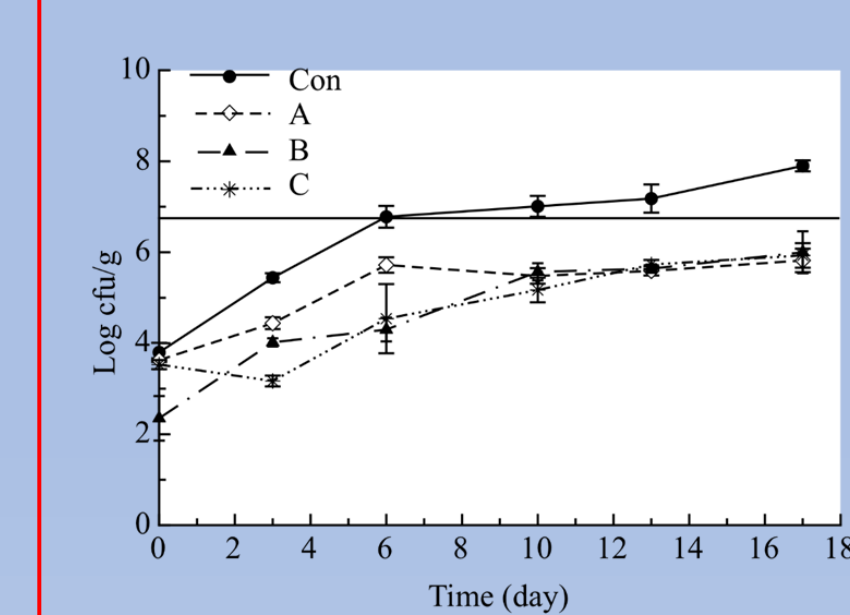
Fruit peel exerted antimicrobial properties, thus maintaining better microbial stability in active (A, B and C) breaded cod sticks.

Figure 5. Psychrotrophic bacteria in cod sticks with dried olive paste



The active samples maintained the microbial concentration below the limit until the end of the observation period.

Figure 6. Psychrotrophic bacteria in cod sticks with pomegranate peel powder



The active samples maintained the microbial concentration below the limit until the end of the observation period.

## CONCLUSIONS

The results obtained in these two case-studies showed a significant improvement in the nutritional quality of fortified samples. In fact, the cod sticks breaded with both dried olive paste and pomegranate peel powder increased the phenol and flavonoid contents, and, consequently, the antioxidant activity. Furthermore, the results showed that adding by-products also microbial proliferation was reduced, without affecting the sensory characteristics. Therefore, it can be concluded that the recycle of by-products could be a sustainable way to reduce the environmental impact and costs associated with by-products disposal, with great advantages for the quality of fish products

## REFERENCES

- Olimpia Panza, Valentina Lacivita, Carmen Palermo, Amalia Conte, Matteo Alessandro Del Nobile. Food by-products for shelf life extension: the case of cod sticks breaded with dried olive paste. *Foods* 2020, 9, 12.  
Olimpia Panza, Amalia Conte, Matteo Alessandro Del Nobile. Pomegranate By-Products as Natural Preservative to Prolong the Shelf Life of breaded Cod Stick. *Molecules* 2021, 26, 2385.