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Valorization of Tomato Dried Peels Powder as Thickening Agent in Tomato Purees

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Abstract

Tomato pomade, consisting of peels and seeds, represents 3-4% of fresh fruit weight. If it remains a waste, it gives rise to disposal problems and aggravate environmental pollution. Our aim was to evaluate the potential of dried peels powder as thickening ingredient in commercial tomato purées. Dried peels were ground in fine and rough sizes and physic-chemically characterized. Samples of creamy and rustic purées with tomato fine and rough dried peels powders at different percentages (0.5-5.0%) were prepared and tested for rheological properties and organoleptic characteristics (colour and flavour). The addiction of 3.0% of fine and 1.0% of rough dried peels powder to rustic purees, and 2.0% of fine dried peels powder to creamy purees resulted as the best combination to reduce the impact of industrial evaporation. The proposed approach could transform a waste in a value-added product to be reused, even in the producer's supply chain itself.

Keywords: Biomass utilization; Waste valorisation; Tomato peels recovery; Thickening agent; Tomato processing

Introduction

A mayor problem faced by the food industry is the accumulation, handling and disposal of processing waste. For this reason, the proposal of recovery food waste is rapidly expanding around the world with an increasing demand for their transformation into useful by-products that help the environmental balance. This is particularly valid of the food and food processing industry, in which waste, effluents and residues can be recovered and often be upgraded to higher value products [1].

Tomato (*Lycopersicon esculentum*) is one of the most consumed vegetables in the world, either as raw fruit or as a processed product. In fact, in Europe and the US, tomatoes are second only to potatoes in economic importance and consumption, and are used in the foodstuff industry as raw material for the production of several products as juices, purée, pastes and canned tomatoes [2]. During processing, a by-product known as tomato pomade is generated. The wet pomade represents, at most, 4% of the fruit weight and on average contains 33% seeds, 27% peels and 40% residues of pulp [3]. In the past, pomade, as other food industry waste, has often been dumped in land-fill sites or used without treatment for animal feed or as fertilizers, but in the last few years there were strong economic pressures to exploit this waste more profitably. In this connection, special attention is drawn to the recovery of valuable substances. Tomato seeds contained a good quantity of proteins and lipids, and could represent an alternative source of oil [4]. The skin was already utilized for extracting the red pigments used as food colour for eggs or juices [5]. Recently, several papers have been reporting on the recovery of lycopene and other carotenoids from tomato waste, using different technologies but so far only few of them have been successfully developed at industrial level, due to low recovery yields and high costs. Tomato peel also contains a large amount of polysaccharides such as fibre and pectin, which represent potential materials to be used as an ingredient in the food industry in fact the beneficial effects of fibre on human health and body function are well-documented. From the industrial point of view, fibre and pectin may also give some important physical properties such as water absorption and viscosity increase to food preparation [6,7]. This properties can make tomato peels, conveniently treated, a cheap and natural replacer to be used instead of other expensive hydrocolloids in food products. Nevertheless, except for the above-cited Farahnaky et al. [8], who have worked on adding dried peel powder in tomato ketchup, no report or study on the application of dried peels as thickening agent and its impacts on the physic-chemical properties of the tomato-based products, was available. The primary aim of this study was to evaluate the potential of dried tomato peels powder at two grain size (fine and rough), as thickening ingredients to be added in the formulation of samples of tomato purées (rustic and creamy), supplied by the same commercial plant where tomato peels have been produced. Starting from the measurement of the water holding capacity, thickening properties of dried tomato peels and their potential use for improving the texture of the products, were tested. Based on the characteristics of the pureés with and without the addiction of dried peels, the final aim was to propose a different approach to tomato pomade recovery, transforming it from a waste to be disposed at all, in a value-added product to be reused, even in the producer's supply chain itself.

Materials and Methods

Materials

Tomato pomade, including seeds and peels, were provided by a tomato-manufacturing unit located in the tomato district of North-East of Italy (Conserve Italia, Ferrara, Italy). Experiments and assays were carried out during the processing season August-September 2013. A total amount of 450 kg of tomato pomade, collected from the processing line in 97 withdrawals of about 4-5 kg each, were stored at 4°C for 2-3 days from the time of sampling. Peels and seeds were separated and cleaned in a water decanter, then centrifuged for 2 minutes at 5000 rpm and finally frozen at -20°C until use for analysis and experiments.

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Peels and seeds, separately, were dried under-vacuum (V090/E oven, I.S.Co. Srl, Italy) at 65°C for 8 hours. Based on the weight loss, the water content was evaluated for seeds as 62.5 ± 3.5% (w/w) and for peels as 72.1% ± 1.2% (w/w). The dried peels were milled using a laboratory milling machine and sieved in two sizes: fine fibre powder (below 4 mm) and rough fibre powder (from 0.4 to 1.2 mm). Both samples were packed in polyethylene bags at 4°C. Commercial formulations of 700 ml glass bottles of creamy and rustic tomato purées were used as basic recipes. Based on Italian regulations, tomato purées can contain only fresh tomatoes, added with salt (NaCl), spices' and citric acid (E330). Different grade of sifting determines the characteristics of the so-called creamy or rustic final products. All chemical used in this research were of analytical grade unless otherwise mentioned.

Preparation of tomato purées added with dried peel powders

Rough fibre (Fg) powder was added at a percentage of 0.25, 0.5 and 1.0% (w/w) to rustic and creamy tomato purées, respectively. Thus, 6 new formulations with rough fibre powder added (3 for rustic and 3 for creamy purées) were produced and tested. Fine fibre (Ff) powder was added at a percentage of 0.25, 0.5, 1.0, 2.0, 3.0, 4.0, 5.0% (w/w), to rustic and creamy tomato purées, respectively. Thus, 14 new formulations with fine fibre powder added (7 for rustic and 7 for creamy purées), were obtained. As a blank, fresh commercial purée before pasteurization was used. Samples and blank were closed in 250 ml glass jar and sterilized at 95°C for 60 minutes, then conserved at room temperature until further analysis.

Chemical and physical characterization of fresh peels and purée samples

After separation from seeds, total (TDF), soluble (SDF), and insoluble (IDF) dietary fiber were determined, with the enzymatic and gravimetric methods described by Proszky et al. [9] using TDF-100 kit obtained from Sigma chemical company, USA. Along with the test samples, blank and reference samples were also analyzed simultaneously in duplicate for comparison. TDF, IDF and SDF contents of the samples analyzed were calculated and expressed on fresh weight basis. Lycopene concentration was determined by HPLC after extraction with 1 methanol:1 tetrahydrofuran (THF) mixture containing 0,5% of butylate hydroxytoluen (BHT) to prevent carotenoids degradation [10]. Lycopene was separated on YMC C30 (250 mm × 4.6 mm, 5 µm) analytical column. A gradient elution with (A) methanol/MTBE/water (81/15/4) and (B) methanol/MTBE/water (6/90/4) from 1% to 100% of solvent (B) for 50 minutes at 1 ml/min flow was carried out. Light absorption was measured with a photodiode array DAD MD-2010Plus (JASCO, Japan) at 450 nm. Pesticides residues and mycotoxins concentration were determined using Quenchers extraction [11] and then analyzed based on the official AOAC methods [12]. Analysis of heavy metals (Cu, Cd, Pb, Zn, Fe, Ni) from fresh and dried peels samples were analysed after dry burning of 10 g in the quartz capsules at 650°C for 4 hours. After complete burning a nitric acid 0.5 N solution was added up to 50 mL. The solutions obtained were used for metals contents determination by flame atomic absorption spectrometry (FAAS) with high-resolution continuum source using a ContrAA-300 device (Analytik-Jena, Germany in air/acetylene flame. The device working parameters (air, acetylene, optics and electronics) were adjusted for maximum absorption for each element. Acetylene was of 99.99% purity. Under the optimum established parameters, standard calibration curves for metals were constructed by plotting absorbance against concentration [13]. Microbial contamination were also quantitatively determined using conventional testing rely on specific and selective media to enumerate and isolate viable bacteria [14]. Samples and blank were also analysed for Brix degrees, acidity, ash and pH [12] after 3 days from preparation. Acidity was determined by titration of sample with sodium hydroxide solution in the presence of phenolphthalein as indicator. In addition, to evaluate organoleptic properties of the new products, blind tests on 20 testers were carried out [15]. After tasting, people were interviewed about flavour, colour, odour and texture of the new formulations in comparison with blank, and opinions registered.

Water holding capacity (WHC)

Two samples obtained mixing 5 g of fine fibre and 400 ml of distilled water were prepared. The first was left on a shaker for 60 minutes at room temperature (cold water), and the second was pasteurized (95°C for 60 minutes) (hot water). Both samples were then dripped on a grid for 90 minutes, up to constant weight. The difference of the final gelatine weight and the initial weight (i.e., absorbed water), divided by the mass of initial powder, was considered as the WHC. The same procedure was carried out to evaluate the WHC of rough fibre. Assays were carried out in triplicate for each sample.

Rheological properties: the Bostwick consistency test

The Bostwick consist meter is a standardized instrument [16] that measures the flow rate (in centimetres) of a known amount of sample on an inclined plane. It is set up with a stainless steel trough 24 cm long, with a reservoir and a gate at one end. This distance is adequate for consistency measurement of tomato concentrated product. Tomato purée is filled into a reservoir and released into trough by opening the gate. Purée flowed in the graduated trough at a standardized temperature (25°C) and for a fixed time (30 sec). Flow distance between the two demarcation lines were determined, in comparison with the flow for blank, and gave a measurement of samples consistency. Triplicate determinations were performed for each samples.

Colour measurements

The colour of samples was evaluated using the method of red standard ceramic plate in the CIELAB colour system, commonly used in the food industry [17]. The lightness (L) and the two colour coordinates, aL and bL for the colour-opponent dimensions red-yellow and green-blue respectively, were measured together with the derived a/b ratio, as an index of colour saturation. Colour tests were carried out in triplicate, as well.

Results and Discussion

Chemical composition of fresh and dried tomato peels

The productive plant, of about 200.000 tonnes of productive capacity, produces juices, sauces, pastes, purée and canned tomatoes for retailer markets and produces 3-4%/year of tomato pomade. To date, Based on Italian regulation tomato pomade is considered as a municipal assimilated waste, at all and burdened by disposal costs to third parties for landfill coverage (about 40%) and animal feed (about 60%). The potential reuse of seeds is out the scope of the present work, so it will not be detailed here. After separation from seeds, fresh and dried tomato peels samples were analysed separately. Reuse of dried seeds (Table 1) summarizes moisture content and the composition in protein, ash, lycopene, dietary fibre, and mineral content of the two samples before sieving. Results have been reported as average values of 15 sampling during the entire campaign. It was found that dried peels content of total dietary fibre (TDF) was 83.54% (w/w) with the following

	Fresh tomato peel		Dried tomato peel	
	Mean	Dev.st.	Mean	Dev.st.
Moisture(% w/w)	72.1	1.82	-	-
Protein (% w/w)	-	-	3.75	0.27
Ash (% w/w)	-	-	2.54	0.32
Lycopene (mg/kg)	5.79	1.02	4.7	0.86
TDF, total dietary fiber (% w/w)	26.08		83.54	
SDF, soluble dietary fiber	2.56	0.29	8.86	2.01
IDF, insoluble dietary fiber	23.52	1.03	74.68	3.33
Sodium (Na)(mg/kg)	-	-	175	43
Potassium (K) (mg/kg)	-	-	1570	231
Calcium (Ca) (mg/kg)	-	-	5850	670
Magnesium (Mg) (mg/kg)	-	-	846	67
Iron (Fe) (mg/kg)	-	-	27	3
Nickel (Ni) (mg/kg)	-	-	2	0.01
Zinc (Zn) (mg/kg)	-	-	46	5
Copper (Cu) (mg/kg)	2.31	0.751	8.244	1.562
Cadmium (Cd) (mg/kg)	0.04	0.009	0.134	0.019
Lead (Pb) (mg/kg)	0.046	0.022	0.177	0.076

Table 1: Chemical characterization of fresh and dried peel samples.

distribution: insoluble dietary fibre (IDF) 74.68% (w/w) and soluble dietary fibre (SDF) 8.86% (w/w). The TDF content was higher than those reported in other vegetables, typically around 60%. As expected, IDF:SDF ratio was 8:1, since vegetables peels are usually rich in cellulose and hemicelluloses [18]. It is worthwhile noting that lycopene content decreased significantly from fresh to dried samples, surely due to its thermal degradation. Due to the high content of mineral cations, especially calcium, magnesium and potassium, dried peels could enrich of nutritive quality the final products, and reduce the amount of sodium chloride added. Both fresh and dried samples were also analysed for 27 active principles of different insecticides, fungicides and herbicides (data not shown), and all of them were into the maximum residue levels (MRLs) provided by European Union regulations [19] for fruit and vegetables. In the field, tomatoes are highly susceptible to fungi contamination - currently known at around 300 species - which can produce aflatoxins and mycotoxins with hepatotoxic, carcinogenic, teratogenic, and mutagenic effects on humans and animal species. They belong to the three most popular generes (Aspergillus spp., Penicillium spp and Fusarium spp). Monitoring the presence of fungal metabolites concentration in food products is particularly important from the safety point of view, and it is mandatory. Any aflatoxins were detected in any of the analysed samples of the tomato peels, both fresh and dried, considering the detection limits of the applied method (<1.00 mg/kg). The presence of relevant concentration of polyphenols in tomato might be able to suppress the synthesis of such toxins and contribute to positive results found. Besides fungal toxins, processed tomato could be easily affected by other microbial contamination, thus determining both organoleptic adulterations and potential health risks for consumers [20]. Microbial analysis of dried peels have evidenced a maximum of 210 UFC/g and in 2 samples the presence of Alicyclobacillus acidoterrestris. Alicyclobacillus acidoterrestris is a thermos-acidophilic, non-pathogenic and spore-forming bacterium that has been isolated and identified in several spoiled commercial fruit juices and concentrates [21]. It is characterized by a good thermal resistance and a good tolerance to a wide range of pH, but the sterilization conditions applied (98°C for 60 minutes) were sufficient to guarantee its inactivation and to exclude contamination into purées due to peels powder addition.

Water holding capacity (WHC) of dried peel samples

Hydration properties of dietary fibre refer to its ability to retain water within its matrix. Materials with strong hydration properties could enhance the viscosity of added food [22], increasing their thickening capabilities. As reported in Table 2, WHC was determined for rough and fine fibre, both with cold and hot water. WHC were 7.9 g/g and 9.2 g/g (g of water per 1 gram of material), for rough peels in cold and hot water respectively, corresponding to about 90% of hydration capacity. Fine peels showed in both cases WHCs' that were similar to those found in other dietary fibre sources like artichoke soybean and seaweeds [23-25]. It is well-known that the structural characteristics and chemical composition of the material play an important role in the kinetics of water uptake. Moreover, it is also known that cellulose and hemicelluloses, the main compounds of IDF, are able to absorb and/or entrap a great amount of water [18]. It is interesting to note that peels, once dried and grinded, have shown WHC greater than the maximum moisture content of the fresh peels. According to the hydration proportion and from the technological point of view, tomato peels could indeed contribute to stabilizing tomato purée, improving its density and reducing free water content. Moreover, from the nutritional point of view, tomato peels could increase the daily intake of indigestible fibres, acting as probiotic food with a beneficial effect also on human health [26].

Addition of fine dried peels powder to creamy tomato purée

Aliquots of fine dried peels powder was added to commercial creamy tomato purée at 7 different percentage from 0.25% to 5.0%, before pasteurization. Samples were then analysed for Brix degree, Bostwick consistency (Bw), pH, acidity and colour (Table 3). Generally, pH of tomatoes has been reported to range from 4.0 to 4.7, and it is determined by its organic acid content, with citric acid being the most abundant [27]. While the addiction did not cause significant differences in pH, acidity and only a slight increasing of °Brix, Bw and colour variations is very interesting, as specified in Figures 1 and 2, respectively. Figure 1 reported variation of Bw (Bw) versus the increasing of fine fibre (Ff) percentage in creamy puree sample. Negative values of Bw means that samples become progressively more consistent and viscous and free water is progressively absorbed by fibre. It is worthwhile noting the high linear correlation (R^2=0.986) up to 5.0% of fine fibre added. The ability of peel powder to absorb water provided a considerable increasing of consistency of formulations and a significant colour variation. In Figure 2 colour variation depending on percentage of fine powder added compared to blank sample were shown. Increasing powder content, tomato sauces became clearer (increasing L values), turning to green (decreasing aL values) and yellow (increasing bL values). The a/b ratio, as dye indicator, decreased consequently. Colour is reported as an indicative quality parameter of tomato products [28]. The comparison of the colour parameters of the samples shows that after the addition of the dried fine fibre powder, a significant increase in the L value was observed (a 1 unit difference in L values of two samples can be detected by the human eyes), while a/b ratio decreased notably from samples from 0.25% to 5.0% of fibre

	Fine peel powder		Rough peel powder	
	Mean	Dev.st.	Mean	Dev.st.
WHC (cold water) (g/g)	4.7	0.1	7.9	0.2
WHC (hot water) (g/g)	5.8	0.1	9.2	0.2

Table 2: WHC of rough and fine fiber calculated as retained grams of water for 1 gram of fiber.

					Color			
	°Brix	Bw (cm)	pH	Acidity (g/100 g)	L	aL	bL	a/b
Blank	9.2 ± 0.1	8.2 ± 0.4	4.5 ± 0.1	0.80 ± 0.01	23.1 ± 0.3	29.3 ± 1.1	12.8 ± 0.3	2.3 ± 0.1
Ff 0.25%	9.2 ± 0.1	7.6 ± 0.5	4.4 ± 0.1	0.80 ± 0.01	23.1 ± 0.3	29.3 ± 1.0	13.0 ± 0.4	2.3 ± 0.1
Ff 0.5%	9.3 ± 0.1	7.2 ± 0.4	4.5 ± 0.1	0.79 ± 0.01	23.7 ± 0.2	28.6 ± 0.6	13.0 ± 0.3	2.2 ± 0.1
Ff 1.0%	9.4 ± 0.1	6.3 ± 0.5	4.5 ± 0.1	0.79 ± 0.01	23.6 ± 0.5	29.0 ± 0.4	13.3 ± 0.5	2.2 ± 0.1
Ff 2.0%	9.9 ± 0.1	5.2 ± 0.3	4.4 ± 0.1	0.79 ± 0.01	23.2 ± 0.3	27.6 ±0.7	13.7 ± 0.4	2.0 ± 0.1
Ff 3.0%	10.1 ± 0.1	2.9 ± 0.3	4.5 ± 0.1	0.80 ± 0.01	23.5 ± 0.3	24.8 ± 0.7	13.3 ± 0.3	1.9 ± 0.1
Ff 4.0%	10.2 ± 0.1	1.6 ± 0.2	4.5 ± 0.1	0.80 ± 0.01	23.9 ± 0.4	24.3 ± 0.7	13.7 ± 0.4	1.8 ± 0.1
Ff 5.0%	10.2 ± 0.1	1.1 ± 0.1	4.5 ± 0.1	0.79 ± 0.01	24.0 ± 0.1	23.6 ± 1.1	3.9 ± 0.3	1.7 ± 0.1

Table 3: Characterization of formulations obtained adding different percentage of fine dried peel powder (Ff) to creamy tomato sauces.

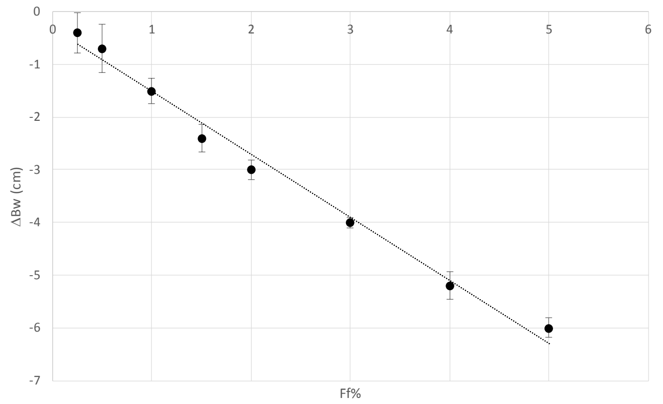

Figure 1: Correlation between B_w and percentage of fine fiber powder (Ff) added to tomato creamy sauce.

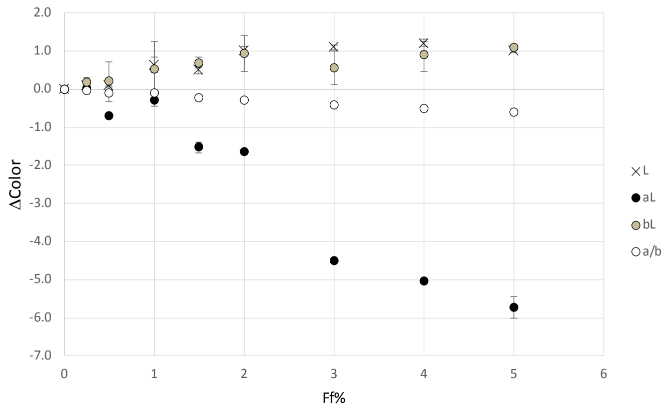

Figure 2: Color variations depending on percentage of fine dried powder (Ff) added to tomato creamy sauce compared to blank sample. Color variations are expressed as lightness (L), aL (red-green), bL (yellow-blue) a/b ratio (dye).

					Color			
	°Brix	Bw (cm)	pH	Acidity (g/100g)	L	aL	bL	a/b
Blank	7.9 ± 0.2	7.5 ± 0.4	4.3 ± 0.1	0.64 ± 0.01	24.8 ± 0.3	27.2 ± 0.8	13.5 ± 0.3	2.0 ± 0.1
Ff 0.25%	7.9 ± 0.2	6.9 ± 0.4	4.3 ± 0.1	0.64 ± 0.01	25.2 ± 0.2	27.5 ± 0.6	13.8 ± 0.2	2.0 ± 0.1
Ff 0.5%	7.9 ± 0.3	6.6 ± 0.2	4.3 ± 0.1	0.63 ± 0.01	25.2 ± 0.2	26.8 ± 0.4	13.9 ± 0.3	1.9 ± 0.1
Ff 1.0%	8.0 ± 0.3	6.1 ± 0.4	4.3 ± 0.1	0.63 ± 0.01	25.5 ± 0.4	26.3 ± 0.5	14.2 ± 0.3	1.8 ± 0.1
Ff 2.0%	8.3 ± 0.1	4.4 ± 0.4	4.4 ± 0.1	0.62 ± 0.01	26.6 ± 0.7	25.6 ± 0.5	14.6 ± 0.7	1.6 ± 0.1
Ff 3.0%	8.3 ± 0.1	3.3 ± 0.4	4.4 ± 0.1	0.62 ± 0.01	26.9 ± 0.5	24.9 ± 0.3	15.3 ± 0.3	1.6 ± 0.1
Ff 4.0%	8.5 ± 0.1	1.8 ± 0.2	4.4 ± 0.1	0.64 ± 0.01	27.6 ± 0.1	23.3 ± 0.3	16.1 ± 0.4	1.5 ± 0.1
Ff 5.0%	8.6 ± 0.1	1.3 ± 0.2	4.4 ± 0.1	0.62 ± 0.01	27.9 ± 0.2		16.5 ± 0.3	1.4 ± 0.1

Table 4: Characterization of formulations obtained adding different percentage of fine dried peel powder (Ff) to rustic tomato sauce.

added. These changes are probably related to the yellowish colour of the powder added to the formulation of the purees samples. According to Goose and Bested [29], an a/b ratio of 1.9 or greater represents a top quality product in terms of colour, and an a/b ratio of less than 1.80 means that the paste may be unacceptable as a desired product.

Thus, based on Bw trend only, fine fibre could be, theoretically added to creamy purees up to 5.0%. However, from colour parameter, it can be concluded that above 3.0%, fine fibre had an overall negative effect on the colour of the final products, and samples are not acceptable. This percentage have been further restricted by blind test, carried out to evaluate organoleptic characteristics in terms of taste, odour and flavour of the 7 new formulations, in comparison with blank. Overall, the limit of acceptability of the addition of fine fibre was even between 0.5 and 2.0%. Below 0.5%, the addition did not involve any perceptible changes, above 2.0%, the product appeared having a strong smell of straw and a sandy texture to be acceptable as tomato sauce. Combining the results of all the tests, fine dried peels powder could be added to creamy purees samples in quantity not higher than 2.0%, to avoid the strong depletion of organoleptic characteristics.

Addiction of fine dried peels powder to rustic tomato sauce

Using the same protocol mentioned in the paragraph 3.3, fine dried peels powder was added to commercial rustic tomato purees from 0.25% to 5.0%, w/w. Chemical and physical analysis of the new formulations are reported in Table 4. As in the previous case, the addiction did not have significant effects on Brix degree, pH and acidity, while strongly affecting consistency and colour. As expected, the commercial rustic texture was less red and clear than the creamy one, and the addition of fibre have led progressively to an evident colour change towards the yellow. The variation of consistency (Bw) is shown in Figure 3. Up to 3.0% of fine powder added, the trend was highly correlated (R^2=0.9911), whereas above 3.0% it loses linearity. The lower quantity of water absorbed than expected could be due to the lower water content of rustic product, so reducing the thickening effect of fibre. The increasing of L and bL values, and the decreasing of aL proved the gradual loss of red and acquisition of clear yellow-orange tone (Figure 4). As in the previous case, in terms of colour, it can be concluded that samples up to 3.0% powder were unacceptable. Blind tests have confirmed that the limit of organoleptic acceptability was 3.0% as well, to avoid a persistent taste of paper, odour of straw and an unpleasant shade of clear yellow.

Addiction of rough dried peels powder to rustic tomato sauce

Rough dried peels powder was added in three increasing percentage

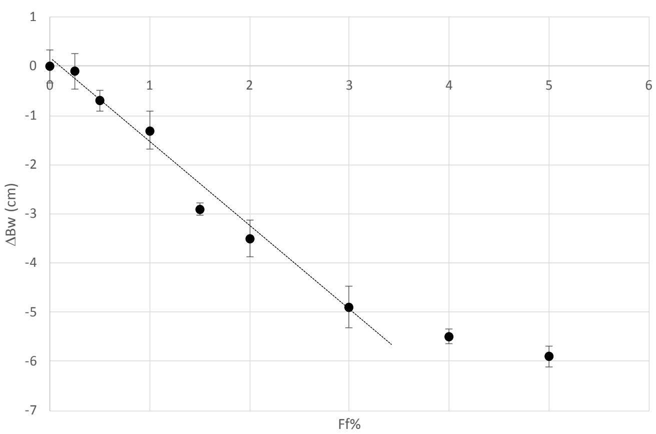

Figure 3: Correlation between B_w and percentage of fine fiber powder (Ff) added to tomato rustic sauce.

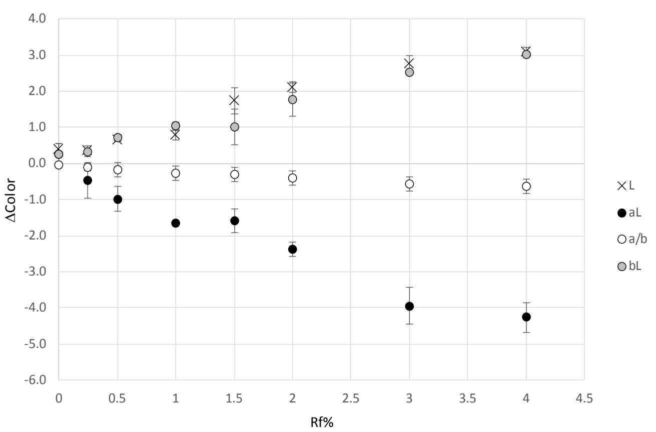

Figure 4: Color variations depending on percentage of fine dried powder (Ff) added to tomato rustic sauce compared to blank sample. Color variations are expressed as lightness (L), aL (red-green), bL (yellow-blue) a/b ratio (dye).

(0.25%, 0.5%, 1.0%) to rustic purees. Chemical and physical analysis of all samples was carried out (Table 5). Although rough dried powder had shown the highest WHC, it could not be used at concentrations above 1.0%, because rough fibre did not well mix with the basic recipe and the resulting preparation could not be proposed. Addiction seemed not to have effects on parameters, except for a decrease of Bw, which corresponds to a non-linear increase of consistency (Figure 5). Colour variation was towards clear tone and yellow/orange (increasing of L and bL, respectively) (data not shown). From the organoleptic point of view, testers judged addiction of rough fibre above 1.0% unacceptable. Addictions of rough dried fibre to creamy sauce were inadequate at any percentage, so results are not reported here.

Effects on thickening of peels dried powders addiction compared to traditional evaporation

Based on the above results, we have demonstrated that adding up to 3.0% of fine dried peels powder to rustic sauce, up to 2.0% to fine dried peels powder to creamy sauce and up to 1.0% of rough dried peels powder to rustic sauce could be acceptable from the organoleptic point of view. It is worthwhile noting that limits have been fixed by the perceived quality of the testers, rather than by the rheological properties of the new formulations, that had permitted to reach higher values of percentage added. Moreover, the WHC of dried fibre powders in the three cases allowed absorbing respectively 10.4%, 15.4% and 9.1% of free water in sauces samples without increasing significantly Brix degree. In tomato industries, water evaporation is usually carried out at low temperature under vacuum, as to avoid product degradation and nutritional depletion. Fresh tomato juice arrives at evaporators with a Brix degree of 5-6 and Bw of 13-15 and, based on Italian regulatory, has to be concentrated up to 8-12 to reach the commercial quality standard of consistency (<10 Bw). Water removal through evaporation is a very energy-intensive operation; previous studies have demonstrated that it consumes about 25% of the overall energy consumption in tomato industrial transformation from fruit to final products [30]. To obtain a comparable effect of fibre addiction on sauces consistency the amount of water to be evaporated is about 20-25% (Figure 6). Depending on the fresh juices initial consistency due to the above-mentioned organoleptic limitations which limit the percentage of addiction, dried fibre addiction could not substitute evaporation at all, but could surely contribute to a finishing treatment, with a considerable costs saving. In fact, drying and grinding of dried fibre could represent a negligible cost in comparison with water evaporation. The ability of the peels powder to absorb water and the increase in the total solids of the samples as a result of the addition of the powder can be considered as the reasons for the increase in consistency. Furthermore, determination of Bw for the subsequent 3 months have demonstrated that at these percentage, fibre permits to absorb another 10% of water during the shelf life. Furthermore, from the industrial point of view, re-inserting tomato peel in the primary flow could reduce the amount of waste in favour of a valuable recovery.

					Color			
	°Brix	Bw (cm)	pH	Acidity (g/100 g)	L	aL	bL	a/b
Blank	8.0 ± 0.1	7.5 ± 0.3	4.4 ± 0.1	0.64 ± 0.01	25.1 ± 0.1	27.1 ± 0.8	13.7 ± 0.1	2.0 ± 0.1
Ff 0.25%	8.0 ± 0.1	6.6 ± 0.1	4.3 ± 0.1	0.64 ± 0.01	25.3 ± 0.4	26.8 ± 0.7	13.4 ± 0.5	2.0 ± 0.1
Ff 0.5%	8.0 ± 0.1	6.2 ± 0.2	4.4 ± 0.1	0.64 ± 0.01	25.5 ± 0.4	26.3 ± 0.5	13.6 ± 0.6	2.0 ± 0.1
Ff 1.0%	8.0 ± 0.2	6.1 ± 0.5	4.4 ± 0.1	0.63 ± 0.01	25.4 ± 0.2	25.9 ± 0.3	14.0 ± 0.2	1.8 ± 0.1

Table 5: Characterization of formulations obtained adding different percentage of rough dried peel powder (Fg) to rustic tomato sauce.

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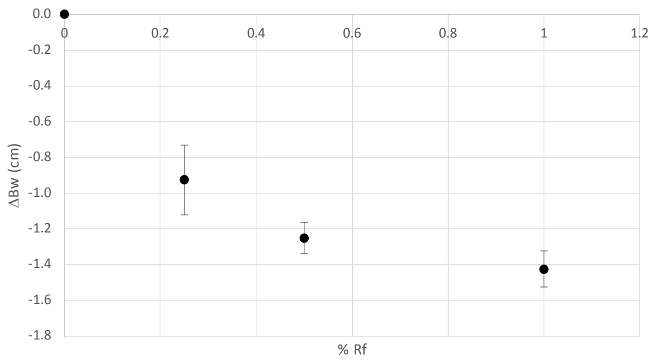

Figure 5: Correlation between B_w and percentage of rough fiber powder (Ff) added to tomato rustic sauce.

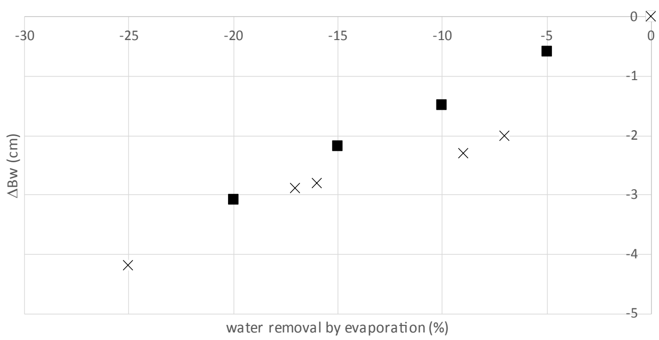

Figure 6: Correlation between B_w and percentage of water removal by evaporation for tomato rustic (x) and creamy sauces.

Conclusions

The direct use of food processing by-products means reducing waste and less environmental damage. For its chemical characteristics, peels fraction of tomato pomade could be used as thickening agent in tomato pureés, to increase product consistency and replace the traditional highly energy-eater evaporation. The dried powder added at adequate percentage to formulations, has shown to be a good candidate for improving the texture properties of products with acceptable colour and flavour variations. Moreover, peels powder have good functional values, e.g., cellulosic matters, pectin and lycopene, and its addition could mean returning these valuable materials to the product.

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