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Nutritional, rheological, and sensory evaluation of tomato ketchup with increased content of natural fibres made from fresh tomato pomace

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ABSTRACT

The aim of this study was to upgrade the tomato pomace by its conversion into a value added product—ketchup with increased content of natural fibre and optimal sensory properties, produced using standard processing equipment. Fresh tomato pomace was homogenized with other ingredients (water, sugar, salt, vinegar, glucose syrup, xanthan gum, guar gum) at 30 °C, then heated at 60 °C, packed and pasteurized. The end of process was determined according to Bostwick consistency value. Chemical composition, colour and rheological properties were measured at six production steps. Ketchup with increased nutritional value was compared with five commercial products in terms of colour, rheological and sensory properties. Tomato ketchup with increased content of natural fibre contained 3.18 g/100 g of total dietary fibre. Although the rheological properties of ketchup with increased fibre content depend mostly on total solids and insoluble particles content, they remained in the limits of standard tomato products. The obtained results are encouraging in terms of the applied technological process since it resulted in a product with sensory properties more similar to fresh or slightly processed tomato. Flavour, viscosity and colour of ketchup with increased nutritional value could be modified to meet the demands of consumers from different markets.

1. Introduction

Tomato (*Solanum lycopersicum* L.) is the second most important cultivated vegetable crop worldwide, especially in Mediterranean countries (Kalogeropoulos et al., 2012; Lenucci et al., 2013). All over the world, tomato is consumed mostly as fresh fruit, and after processing into various products such as tomato juice, paste, sauce, puree and ketchup (Capanoglu et al., 2008; Lenucci et al., 2013). The industrial processing of tomato is accompanied by the generation of waste—tomato pomace (seeds, pulp and skins) which comprise about 1–5% (w/w) of the total tomato processed into tomato products (Albanese et al., 2014; Capanoglu et al., 2008; Lenucci et al., 2013; Ruiz Celma et al., 2009). Large quantities of tomato processing by-products (mainly peels and seeds) are generated by tomato industrial processing plants, in which the most serious problem is the accumulation, handling, and disposal of processing wastes and by-products (Lenucci et al., 2013). On the other hand, they are available at no additional raw material cost, and their utilization can contribute to the creation of value added products and their commercial valorization, which is the latest trend in development of functional food of vegetable origin (García Herrera et al., 2010; Sarkar and Kaul, 2014). Attempts of tomato waste reuse streams resulted in producing of feed stuff and biocolourants (Laufenberg et al., 2003) or in adding of tomato pomace as a potential thickener

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to tomato ketchup as hydrocolloids replacer and improver of colour and texture of the product (Farahnaky et al., 2008). Also, the drying process (convection or freeze drying) has been shown to be the most favourable pre-treatment, followed by milling and frozen storage at −20 °C (O'Shea et al., 2012).

Dietary fibre includes a mixture of plant carbohydrate polymers, both oligosaccharides and polysaccharides, and is classified as soluble or insoluble in water (Johansson et al., 2000). Dietary fibre intake is similar in Mediterranean and non Mediterranean European countries (about 20 g per capita), but its origin is different—fruits and vegetables are the primary source in Mediterranean countries, while cereals dominate in other countries. In addition, dietary fibre from fruits and vegetables represent a carrier of bioactive compounds (vitamins, carotenoids, polyphenols), which are usually deficient in most diets (Goñi and Hervert-Hernández, 2011). According to Englyst and Hudson (1996), tomato contains 7.4% soluble and 11.4% insoluble fibres (% dry matter). Soluble fibres increase viscosity, while insoluble fibres are characterized by their porosity and low density and diet supplemented with dietary fibre influences food to be low in calories, cholesterol and fat (Englyst and Hudson, 1996; Johansson et al., 2000). Insoluble and soluble fibres have different roles in disease prevention: insoluble fibre regulates intestinal functions and water absorption, while soluble fibre influences glucose absorption in the small intestine and reduces blood cholesterol (Yangilar, 2013). Therefore, dietary fibre could influence the reduction in the risk to the chronic diseases like cardiovascular disease, obesity, diabetes, and different types of cancer (Alvarado et al., 2001). Moreover, tomato fibre is rich in minerals, such as K, Mg, Ca and low in Na, Fe and Zn (Navarro-González et al., 2011). Fruits and vegetables are the primary sources of pectin, soluble dietary fibre with health-enhancing properties, thought to lower blood cholesterol and delay gastric emptying (Yangilar, 2013; O'Shea et al., 2012). Pectin plays an important role in the textural changes of fruits during heat treatment or other processing operations. Total pectin substances include protopectin and pectic acid partly esterified by methyl groups (Prasanna et al., 2007). Two major enzymes that degrade pectin are polygalacturonase (PG) and pectin methylesterase (PME). PG cleaves the polygalacturonic acid chain, reducing its length and thus decreasing the viscosity of tomato juice (Anthon et al., 2002). On the other hand, PME catalyzes the removal of the methyl groups, increasing the number of free carboxyl groups which can bind Ca^{2+} and cross-link pectin chains, leading to increased firmness of final product (Anthon et al., 2002; Cámara Hurtado et al., 2002). Protopectin is water-insoluble, high molecular weight pectin fraction which is converted during ripening, storage and processing operations into soluble polyuronides (Prasanna et al., 2007). Pectic substances have a major influence on the quality, stability, and viscosity of tomato ketchup (Sharoba et al., 2005).

Rheological properties of tomato products are considered as one of the most important quality attributes, since they influence product processing parameters, especially flow properties during transport, as well as consumers' acceptability. Beside agronomic (variety, maturity, etc.) and processing (heat treatment, mashing, storage, etc.) parameters, the differences in rheological behaviour are the consequence of specific tomato products structure. From a structural point of view, tomato products are dispersions consisting of particles suspended in a colloidal serum. While suspended particles (pulp) include aggregated or disintegrated cells and cell wall material such as cellulose, lignin, hemicelluloses and water-insoluble pectic materials, the continuous phase (colloidal serum) is mostly composed of water-soluble pectins and other tomato components soluble in aqueous solution (Bayod et al., 2007; Tiziani and Vodovotz, 2005). Tomato ketchup represents a concentrated dispersion of insoluble matter in aqueous media, and due to its complex structure, it exhibits non-Newtonian, shear-thinning and time-dependent rheological behaviour with yield stress (Bayod et al., 2008; Koocheki et al., 2009; Sharoba et al., 2005).

Ketchup is one of the most popular tomato products in the global market and requires limited equipment and simple processing (Alam et al., 2009; Sharoba et al., 2005). In the production process, thickening agents are used for their ability to act as water binding and bodying agents (starch, carboxymethylcellulose, guar gum, xanthan gum), to increase the consistency, and to prevent serum separation from ketchup (Koocheki et al., 2009; Mert, 2012). From the consumers' point of view desirable characteristics of ketchup are intense red colour, high consistency, sweet and tomato taste and spicy flavour (Agribusiness Handbook, 2009; Bannwart et al., 2008). In order to meet such consumers' expectations, avoid ratio change between insoluble–soluble fibres and change of physicochemical properties (Elleuch et al., 2011), as well as to reduce the production costs, the production process used in this study was created in way to avoid long heat treatment.

The aim of this study was to upgrade the tomato juice by-product (tomato pomace) by its conversion into value added product (tomato ketchup) with increased content of natural fibre and acceptable rheological and sensory properties using standard processing equipment.

2. Material and methods

2.1. *Materials*

Tomato pomace used for production of tomato ketchup with increased content of natural fibre was obtained from commercial tomato used in an industrial plant (Selenča, Serbia) for tomato juice production. Beside tomato pomace, this value added ketchup contained other ingredients, listed in Table 1.

Commercial white refined sugar, table salt and vinegar (9% acetic acid) were used in the ketchup production. Glucose syrup was purchased from Jabuka (Pančevo, Serbia), while guar and xanthan gum were purchased from Carl Roth (Karlsruhe, Germany). Ketchup produced in this research (P1—Ketchup with increased fibre content) was compared in terms of rheological and sensory properties with five commercial products [P2—"Gurman" professional

Table 1 – Formulation of tomato ketchup with increased content of natural fibre.

Tomato ketchup	Quantity (kg)*
Fresh tomato pomace (peel, seed and pulp particles)	67.49
Water	83.01
Sugar	10.08
Salt	2.33
Vinegar	3.10
Glucose syrup	4.65
Xanthan gum	0.13
Guar gum	0.13

* The quantity is referred to the minimum production batch of the industrial plant (150 kg of final product).