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TOMATO FIBRE AS POTENTIAL FUNCTIONAL FOOD INGREDIENTS

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A b s t r a c t

Vegetables are a very important element of the human diet due to the fact that they are carriers of many bioactive substances. Tomatoes are among them as a valuable source of dietary fibre, antioxidants (carotenoids, flavonols, vitamin C, tocopherol). Unused tomato waste resulting from the production of juice and paste can be used for making functional foods.

The aim of the research was to characterise tomato fibre as a carrier of bioactive substances and assess its usefulness as a functional component of foodstuffs.

Our research results showed that tomato pomace is a rich source of dietary fibre and in particular of its active fractions. However, the expected amounts of carotenoids including lycopene were not found out in them. Still it reveals an ability to bind metal cations. The tomato preparation can be regarded as a potential functional food additive.

MŁÓTO POMIDOROWE JAKO POTENCJALNY FUNKCJONALNY SKŁADNIK ŻYWNOŚCI

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S ł o w a k l u c z o w e: młóto pomidorowe, substancje bioaktywne, składnik funkcjonalny.

A b s t r a k t

Warzywa są bardzo ważnymi elementami pożywienia człowieka jako nośniki wielu substancji bioaktywnych. Do nich zaliczane są też pomidory jako cenne źródło błonnika pokarmowego, antyoksydantów (karotenoidów, flawonoli, witaminy C, tokoferolu). W tworzeniu żywności funkcjonalnej mogą być wykorzystane powstałe z produkcji soków i przecierów niezagospodarowane odpady pomidorowe.

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Celem badań była charakterystyka młóta pomidorowego jako nośnika substancji bioaktywnych i ocena jego użyteczności jako składnika funkcjonalnego żywności.

Wykazano, że młóto pomidorowe jest bogatym źródłem błonnika pokarmowego, w tym w szczególności jego aktywnych frakcji. Nie stwierdzono w nim natomiast spodziewanej ilości karotenoidów, w tym likopenu. Wykazuje ono zdolność do wiązania kationów metali. Preparat pomidorowy może być uznany jako potencjalny funkcjonalny dodatek do żywności.

Introduction

Vegetables as carriers of numerous bioactive substances are very important components of the human diet. Tomatoes are among the most popular vegetables in our country. They are a rich source of antioxidants (carotenoids, flavonols, vitamin C and tocopherol) and potassium. What is more, they contain very valuable from a nutritional point of view components such as: vitamins D, K and from the B group as well as dietary fibre (BOROWIAK 2007, FANASCA et al. 2006).

As a source of antioxidants tomatoes are first and foremost associated with the presence of carotenoids. Carotenoids are a group of bioactive compounds which in plants fulfil a protective role and the main pigment in tomatoes – lycopene – is responsible for the characteristic red colour of the fruit. In ripe tomatoes lycopene makes 80–90% of all caretonoids.

Dietary fibre is a natural component of plants; it is a mixture of compounds resistant to the activity of digestive enzymes in the human digestive system. Admittedly, dietary fibre has no nutritional value but is indispensable in a diet as it fulfils other pro-health functions. Soluble fibre has the ability to reduce the levels of LDL cholesterol and at the same time improves proportions between the desirable HDL and undesirable LDL fractions, and slows down the hydrolysis and absorption of nutritional components. The insoluble fibre fraction stimulates peristalsis and accelerates the flow of intestinal contents. The ability to bind heavy metals is a particular advantage of dietary fibre (BARTNIKOWSKA 1995, BORYCKA 2012, GÓRECKA 2004).

It is worth mentioning that a lot of research points to a correlation between consumption of tomatoes and their products and reduced risk of cancer diseases (BOURN and PRESCOTT 2002, SHI and LE MAGUER 2000).

In Poland tomatoes are a valuable raw-material used in the fruit and vegetable processing industry. Literature data (ZALEWSKA-KORONA and JABŁONSKA-RYŚ 2012) indicate that ca. 150 thousand tonnes of field-grown tomatoes, i.e. ca. 50% of entire crops, are processed annually, mainly into a tomato concentrate and to a lesser degree into juices, ketch-up and other sauces; in smaller amounts – into canned tomatoes and as additives to meat, fish and vegetable products. A post-production waste in these processes is tomato pomace.

On the one hand, worldwide trends in waste management aim at converting as much waste as possible into useful products; on the other hand, investigations are carried out into the ways of minimising the risk for the natural environment not only by eliminating waste but also by converting it into useful components (OKONKO et al. 2008). The most popular way of fruit and vegetable waste management, including pomace management, is using it for fodder due to the high contents of such components as: organic acids, nitrogen-free compounds, saccharides, fatty substances and vitamins. The result is reducing the costs of feeding animals (ŚWIĄTKIEWICZ and KORELESKI 2003, TARKO et al. 2012). Fruit and vegetable pomace, when used for the production of ethanol, can become an important source for biofuel. Fermentation of saccharides into alcohol is perceived as one of the best methods to get out the cumulative energy from the biomass (CHATANTA et al. 2008). Fruit and vegetable waste is also a rich source of dietary fibre. What is more, the colour fruit and vegetable waste can be a source of natural, biologically active pigments (and tomato pomace is a carotenoid carrier).

Tomato pomace is also used in beauty and food sectors. It is worth mentioning that in 2011 J. Bajerska from Poznan University of Technology prepared special rye bread on the basis of the tomato pomace enriched leavening. The product was a finalist of the 2011 Poznan Invention Competition (*Portal innowacji*. 2013). It was the inventor's intention to make the product counteract obesity and factors contributing to the development of sclerosis and diabetes and at the same time be tasty. However, a considerable part of this valuable raw material goes to rubbish dumps.

The aim of our investigations was to characterise tomato pomace as a bioactive substance carrier and to assess its usefulness as a functional component of foodstuffs.

Materials and Methods

In our work we used tomato pomace obtained during the tomato concentrate production in the Fruit and Vegetable Processing Industry Plant (ZPOW) in Milejów.

In the organoleptic analysis we used canned pâtés which are commonly available on the domestic market: Mazowiecki pâté – PM and poultry pâté – PD.

In the investigated preparations we determined the TDF (total dietary fibre) content by means of the AOAC method (PROSKY et al 1984) in the course of which the ash content was determined and the Kjeldahl method was used to determine the amount of protein. To determine the complete chemical composition of fibre preparations, the fat content was determined in the ether extract using the Soxhlet method as it is recommended by Polish standards (KUŁAS-KREŁOWSKA 1993). Moreover, the saccharide content in the fibre samples was determined according to the AOAC reference procedures (AOAC 1990). Soluble and insoluble parts of dietary fibre were determined by the Aspa method (Asp 1983).

In the investigated preparations dietary fibre fractions (cellulose, hemicellulose, lignin) were determined by the detergent method according to Van Soest, and McQueen and Nicholson (VAN SOEST and MCQUEEN 1973, MCQUEEN and NICHOLSON 1979).

Total pectin fractions were isolated in high temperatures with the use of 0.5 M HCl according to the procedure developed by KING (1987) whereas the water soluble fraction was isolated by Kawabata's extraction method (KAWABATA 1997). To determine the uronic acid contents in extracts we used Bitter's borate-based spectrophotometric method (KŁYSZEJKO-STEFANOWICZ 1972).

The cation-exchange capacity was determined on the basis of MCCONNELL'S procedure (MCCONNEL et al. 1974).

Mineral characteristics of pomace preparations included dry mineralization of samples and atomic absorption spectrometry (AAS) (KUŁAS-KREŁOWSKA 1993). To determine cadmium and lead contents we used the flameless method with use of the graphite cuvette.

In all investigations the average of was calculated from 9 measurements.

The sensory evaluation based on a 5-point scale reference card for meat pâtés (PIECZONKA 1995) was carried out by a panel of 11 persons of verified sensory sensitivity and meeting the requirements of the PN-ISO standards (8586-1:1996, 8586-2:1996, 6658:1998). They evaluated: general appearance and colour, texture, taste and flavour of meat pâtés with and without additives. The following importance coefficients (determined by the experts' estimation method) were attributed to particular product characteristics: 0.15 – to appearance and colour, 0.25 – to texture and 0.60 – to taste and flavour. Using the importance of particular characteristics, the sensory evaluation of total quality was calculated.

By comparing two independent samples and two dependent samples (Student's t-test) (DOBOSZ 2001), it was analysed whether the tomato pomace additive to a pâté had any impact on the sensory quality of the final product.

Results and Discussion

The investigated preparation was characterised by an orange red colour. The examined tomato waste contained ca. 12% of fat, significant amounts of proteins (ca. 21%) and small amounts of total saccharides (ca. 8.5%) – Table 1.

The research by Del Valle and co-workers (DEL VALLE et al. 2006) confirms the above contents of proteins (ca. 19%), although indicates lower by half levels of fat (ca. 6%) and higher contents of total saccharides (ca. 26%).

Table 1

Chemical characteristics of tomato pomace (on a dry matter basis (DMB))

Components	Parameter	$\bar{x} \pm S_x$
Protein	$n \cdot 6.25$ [%]	21.06 ± 0.92
Fat	[%]	13.92 ± 1.19
Saccharide content	total saccharides content [%]	8.42 ± 0.08
	saccharose content [%]	0.11 ± 0.01
Bioactive components	carotenoid content [mg/100 g]	1.52 ± 0.03
	lycopene content [mg/100 g]	0.004 ± 0.001

The differences in determinations can be caused by different varieties of the raw-materials used in processing, the country of origin and applied research methodology. On the other hand, PACHOŁEK (2010) determined a similar protein content in tomato pomace (ca. 24%) and considerably higher in tomato seeds (ca. 33%), and higher, almost twice as high, fat content (in pomace and seeds – ca. 21% and 22.5%, respectively).

Carotenoids can be a particularly important bioactive component of tomatoes and tomato waste. Research work reveals that they can reduce or stop negative changes in foods (CLINTON 1998, HARMUŁKA and WAWRZYNIAK 2004). Lycopene and β-carotene are among basic carotenoids appearing in tomato fruits. The composition and content of carotenoids in tomatoes, and in particular of lycopene, depend to a large extent on the fruit variety and its ripeness. According to Sadler (SADLER et al. 1990) the average lycopene content in field-grown tomato varieties can range between 4.0 to 11.0 mg/100 g, whereas Harmułka and Wawrzyniak (2004) speak about the levels of 0.9 ÷ 7.74 mg/100 g of fresh mass, depending on the fruit variety and ripeness.

The investigated tomato waste proved to be a rather poor source of carotenoids, the content of which was determined at the level of 1.5 mg/100 g, including only 0.004 mg/100 g of lycopene. In the available literature on the topic no information was found concerning the morphological structure of the tomato and the location of carotenoid (including lycopene) particles in it, therefore we can only make conjectures about the causes of this phenomenon. Literature sources claim (HARMUŁKA and WAWRZYNIAK 2004) that carotenoids are very sensitive to oxygen, especially in high temperatures. It is worth mentioning that after the raw-materials have been processed, carotenoids including lycopene, are more easily accessible owing to a larger surface of the processed products. Moreover, their chemical structure changes under the influence of temperature and they enter the processed products more easily (HARMUŁKA and WAWRZYNIAK 2004). Thus it can be assumed that very few of them remain in the pomace after the carotenoid rich paste has been obtained.

The research results for tomato waste dietary fibre and its fractional composition included in Table 2 show that it is a valuable source of fibre as it contains 52% ÷ 54% of total dietary fibre (TDF). It is worth mentioning that this level is stable despite the application of different methods of its determination. The research results compared with literature data regarding other vegetable waste also prove that the tomato preparation is characterised by a high TDF level, in many cases much higher than that for other vegetable waste. In their research Del Valle and co-workers (DEL VALLE et al. 2006) obtained similar results for TDF contents (ca. 59%). The literature on the subject gives different TDF values for other vegetable pomace; for example in carrot pomace BORYCKA and GÓRECKA (2005) found ca. 65% of TDF, whereas in sugar beet pomace Tarko and co-workers (2012) determined only ca. 13% of total dietary fibre.

Table 2

Dietary fibre content in tomato pomace (on a dry matter basis (DMB))

Components		Parameter [%]	$\bar{x} \pm S_x$
Dietary fibre	total	TDF	52.60 ± 0.77
	–	insoluble	50.13 ± 2.76
		soluble	4.29 ± 0.40
		NDF	48.42 ± 0.44
		cellulose	15.15 ± 0.34
		hemicellulose	10.80 ± 0.53
		lignin	22.76 ± 0.36
		total pectins	4.48 ± 0.14
		water soluble pectins	0.12 ± 0.03

The investigated tomato pomace contains over 48% of detergent dietary fibre (NDF), which in comparison to other vegetable waste is a significantly high value (Table 2). For example: literature sources (BORYCKA and GÓRECKA 2005) quote its content in carrot pomace as NDF < 35%. It is worth noticing that research results obtained by NAWIRSKA and UKLAŃSKA (2008) also point to a significant effect of the carrot variety on the fractional fibre content in pomace. Apparently the difference can reach as much as ca. 10% NDF. On the other hand Schmidt and co-workers (1999) determined the NDF content in tomato from the *Cucurbitaceae* family to be at a low level of ca. 15%.

The presence of fractions containing reactive functional groups, i.e. lignin, hemicellulose and pectins accounts for the dietary fibre functionality. Thus, thinking about the pomace as a potential functional food additive the relatively high contents of lignin and hemicellulose in comparison to other vegetable waste (among others, carrot pomace) must be emphasised (BORYCKA and GÓRECKA 2005, NAWIRSKA and UKLAŃSKA 2008). Apart from this, tomato pomace is a rather poor (ca. 5%) source of pectins in comparison to, for example, carrot pomace (ca. 8%) (BORYCKA and GÓRECKA 2005, NAWIRSKA and UKLAŃSKA 2008). In comparison to fruit pomace it is characterised by significantly higher contents of lignin and hemicellulose fractions, but a lower content of pectins (BORYCKA 2000, 2012). The function of the above mentioned presence of fibre fractions and at the same time an indicator of the ability to bind, among others, metals including heavy metals, is the determined CEC – i.e. ability to bind sodium ions (BORYCKA 2012).

Literature data indicate that ion-exchange resin capacity is related to the number of ions which can be exchanged per unit mass of ion-exchange resin and is defined in equivalents or millequivalents per a gram of the ion-exchanger. McConnell and co-workers (MCCONNEL et al. 1974) proved that a significant number of fibre varieties behave like a monofunctional resin poorly exchanging a cation. However, it must be mentioned that fruits were characterised by higher CEC capacity than vegetables (e.g. apples – 1.9 mE/g, oranges – 2.4 mE/g, whereas carrots – 0.15 mE/g, and potatoes – 0.04 mE/g) (GÓRECKA 2004).

In the case of tomato waste CEC was determined at the level close to that of currant pomace and slightly lower than in apple-currant pomace preparations of the same weight (0.26 mEq/1 g and 0.30 mEq/1 g, respectively) (BORYCKA 2000). It must be mentioned that both compared pomace preparations turned out to be good sorbents for heavy metals, which lets us expect a metal sorption ability in the case of tomato preparations (GÓRECKA 2004).

CASTERLINE and KU's thesis (1993) that the presence of metals in the environment can affect properties of acidic polysaccharides due to the creation of insoluble metal-polysaccharide complexes is also worth remembering.

Research results included in Table 3 let us qualify tomato waste preparations as potential food additives because the levels of heavy metals contained in them do not exceed the permitted level defined in the Minister of Health's Regulation concerning acceptable safe limits for chemical and biological contaminations in foodstuffs (Rozporządzenie... Dz.U. nr 37. poz. 326.).

To check the effect of a tomato additive on the sensory quality of selected food products, a sensory analysis (5-point scale) of meat products enriched by the investigated preparation was carried out (Table 4).

Table 3

Contents of selected metals in the tomato fibre preparation

Quantity	CEC mE/g	Metal levels [μg/g ± SD]	
		Cd	Pb
Content	0.22 ± 0.02	0.038 ± 0.005	0.25 ± 0.09

Table 4

Sensory analysis results for pâtés with the tomato pomace preparation additive

Product		Additive [%]	Statistical measures	
			$\bar{x}$	S_x
Pâté	Poultry	0 1	4.13 4.11	0.47 0.53
	Mazowiecki	0 1	4.54 4.59	0.53 0.36

Table 5

Effect if the tomato pomace additive on the sensory quality of pâtés – results of Student's *t*-test

Products compared		"t-value"
Poultry pâté PD-0	PD-BPOM	0.102
Mazowiecki pâté PM-0	PM-BPOM	0.375

The asterisk (*) means that the *F*-test value allows us to reject the null hypothesis (at the level $\alpha = 0.05$)

The arithmetic mean values of the evaluation on a 5-point scale imply that a 1% addition of tomato pomace affected the sensory quality of the final product, which was later verified by the Student's t-test. This led to a thesis that a tomato fibre additive to a pâté affects the sensory quality level of the final product.

The statistical analysis results showed that a 1% additive of tomato pomace to examined pâtés does not significantly affect their sensory quality.

Conclusions

1. The investigated tomato pomace fibre preparation was characterised by a high (ca. 50%) content of dietary fibre.
2. The preparation distinguished itself among other waste fruit sources by higher levels of lignin and hemicellulose active in metal exchange reactions.
3. Results of CEC tests indicate that the ability of the pomace preparation to bind cations is relatively high in comparison to other waste fruit sources.

4. The tomato preparation can be considered a potential functional food additive.

5. Our examinations proved that the tomato pomace preparation can be an attractive fibre additive to the pâtés – Mazowiecki and poultry ones – as 1% of this additive does not have a significant effect on their sensory quality.

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