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PHYSICOCHEMICAL AND NUTRITIONAL CHARACTERISTICS OF TOMATO SEED MEAL FROM WASTE OF A TOMATO PROCESSING PLANT

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Abstract: Although there are scientific and technological advancement, still the world food situation is critical and tending to be worse. But without any doubt in the future good recourses will be applied for unexploited resources sufficiently like the wastes in the food industry. We mainly focus the evaluation of protein quality and fat composition and characteristics in tomato seeds available from industrial waste. The results showed 28.0% protein content, 37.9% raw fat, 20.4% raw fiber, in vitro digestion 61.6%, available lysine 3.02g AA/100g of protein and tryptophan 0.97 g AA/100 g of protein. The unsaturated fatty acid content was 83%, mainly linoleic acid followed by oleic acid. The physical and chemical characteristics of fat obtained were compared with the fat coming from maize oil, cotton seed oil and sunflower seed oil. It is possible suggest that tomato seed oil can be considered as a potential source of edible oil. The presence of trypsin inhibitor and lectins were not detected. Finally, the functional properties studies showed that the meal had fat absorption and emulsifying capabilities.
Keywords: Agro-industrial waste, foods, waste, reutilization

INTRODUCTION

Currently, one of humanity's most urgent problems is the production of food in sufficient quantities to feed the growing number of people living on the planet. The world population is approximately 8045 million (United Nations Population Fund), and it is evident that a good part of this population does not have sufficient food. This phenomenon has led to the need to increase food production at an accelerated pace. Despite scientific and technological advances, the world food situation is critical and tends to worsen, however, there is no doubt that in the future the use of resources that have not been sufficiently exploited as they will have to be applied to a greater extent waste from the food industry (Corredor & Pérez, 2018; Brennan & Browne, 2021; Liu et al., 2023).

For nutrition, humanity could depend on some 300,000 edible plant species, of which only about 150 of these are commercially grown and more than half of the proteins and calories we take from plants come from three main crops: corn, rice and wheat (Sands et al., 2009), this means that if something were to happen to them we would be forced to change our diets on a massive and global scale, if the world is to have a realistic chance of attacking the problems caused by an ever-increasing population, it will have to resort to new and unconventional sources of proteins, which, properly managed, would contribute to solving the food problem (Barragán and Col, 2008; Azevedo and Campagnol, 2014; Campo Vera et al., 2016, Kusumasari et al., 2024).

Approximately more than one hundred million tons of protein are required annually for human consumption, and despite the scarcity, little or nothing has been done to recover the very high amounts of nutrients such as carbohydrates, lipids or proteins that are lost as waste during the processing of many fruits and vegetable products, which in the best of cases are used as livestock feed, but which, in the worst, contribute a lot to the long list of environmental contaminants (Milena and Col, 2008; Matthaus and Özcan, 2012; Serrat-Díaz et al., 2016; Neuza and Col, 2016).

In 2020, global tomato production was more than 186 million tons, and around 36.8 million tons of global production are processed fresh, producing large quantities of waste such as peels and seeds (FAO, 2021; Branthôme, 2020). For these reasons, the objective of this work was to investigate the physicochemical and nutritional characteristics of the waste obtained from tomato processing.

MATERIALS AND METHODS

The seed used was obtained from a tomato processing company for the production of tomato paste and puree and consisted of remains of pressed pulp, skin and especially tomato seeds of the guaje, ball and ponderosa varieties. Three lots were worked between the months of June to August. These wastes were washed and seeds were mainly obtained by rubbing and soaking in cold water, then were dehydrated in an oven at 60°C for 48 hours and subsequently ground in a Wiley mill mod 3383 (Thomas Scientific, Swedesboro, New Jersey, USA) with a 20-mesh sieve, obtaining what was called whole wheat waste flour tomato.

EXPERIMENTAL DESIGN

CHEMICAL ANALYSIS

Proximal analysis was carried out on the whole flour from tomato seed waste in accordance with AOAC techniques for each determination. The samples were worked in triplicate in the three batches obtained from the different months of the study period. For the determination of crude fat instead of ether, a 2:1 mixture of chloroform-methanol was used and for the calculation of protein from the determination of Nitrogen, the conversion factor 5.85 was used as it is the most used in the bibliography consulted. An analysis of variance was performed using the Duncan method to determine if there was a difference between the three lots analyzed.

TOXICOLOGICAL ANALYSIS

The determination of phytohemagglutinins was carried out by the method of Jaffé and collaborators (1974), trypsin inhibitors by the method of Kakade and collaborators (1969) and Saponins by the Liebermann-Brouchard reaction (Kuklinsky, 2000).

IDENTIFICATION AND QUANTIFICATION OF FATTY ACIDS

It was performed via gas chromatography in a Varian mod 3700 chromatograph (Varian Instruments, Walnut Creek, CA) equipped with a flame ionization detector, recorder and integrator system and data processor CDS 111. The condition for using this technique is that the sample must be volatile, so it is necessary to transform fatty acids into methyl esters using reagents such as boron trifluoride, sodium methoxide or sodium methylate. The injector temperature was 220ºC, the detector 240ºC and the column temperature 180ºC, with a 15% diethylene glycol column on Chromosorb, WHP 800/100.

CHEMICAL AND PHYSICAL CHARACTERIZATION OF FAT

Iodine value, saponification value, acidity value, peroxide value, density and refractive index were determined according with the official techniques.

FUNCTIONAL PROPERTIES

Fat absorption was determined by the method of Sosulski and collaborators (1976), emulsifying capacity by the method of Huffman, Lee and Burns (1975) and foaming capacity by the method of Mohanty, Mulvihill and Fox (1988).

AMINO ACID COMPOSITION

The amino acid composition in the samples was determined using reversed-phase HPLC according to the methodology described by Sepúlveda and collaborators (2021). The samples were subjected to acid hydrolysis with 6N HCl at 145°C for 4 h. The amino acids were analyzed in a Technicon NC-2P Autoanalyzer (Technicon Equipment Corp., USA), operated with a 470x4 mm analytical column. The run was performed at 60 °C and a flow rate of 0.6 mL/min. The amino acids Lysine (as available lysine) and Tryptophan were further determined by the methods of Hurrel, Lerman and Carpenter (1979) and Spies and Chambers (1948) respectively.

FLOUR DIGESTIBILITY

In vitro digestibility determination was carried out by the method of Hsu and collaborators (1977).

RESULTS

Of the three batches taken for the proximal chemical analysis, as mentioned, three different batches were taken in the months of June, July and August, which were analyzed in triplicate, obtaining a dry basis content of ashes 4.1 (0.15) %, fat crude 40.5 (0.38) %, crude protein 30.0 (1.93) %, total dietary fiber 21.8 (2.64) % and nitrogen-free extract obtained by difference of 3.6 (1.0) %. Humidity did present statistical differences with respect to the three lots, 7.0%, 6.9% and 5.5%, with the average being 6.47 (0.84) %.

In general, the fat and protein contents are high, which would represent a good source of these nutrients, and it is worth mentioning that no statistical difference was found between the lots sampled in the different months in any of the parameters.

Table 1 shows the obtained composition of amino acids, as well as the content of available lysine and tryptophan determined separately, compared with the FAO standard to give a better understanding of this composition.

Amino acid	Tomato seed flour	FAO Standard (2007)
Methionine + Cysteine	24.9	26
Lysine	46.9	52
Isoleucine	30.7	31
Leucine	40.6	63
Histidine	26.2	18
Phenylalanine + Tyrosine	40.5	46
Valine	30.5	42
Threonine	43.0	27
Arginine	31.7	-
Tryptophan	9.70	7.4
Available lysine	30.2	-

Table 1. Amino acid composition of defatted tomato seed flour compared to the FAO standard (mg AAC/1 g Protein)

-Not reported. Recommended values for children between 3 and 10 years old

The in vitro digestibility of tomato seed flour was 61.61%, however, this result should be taken with caution since it was determined in vitro, and according to some authors, fecal amino acid digestibility values are typically higher than ileal amino acid digestibility values, particularly for poorly digested protein sources (Rowan et al., 1994; Ratriyanto et al., 2010).

Regarding toxicological analyses, all batches gave negative results for trypsin inhibitors, phytohemagglutinins and saponins.

Table 2 shows the fatty acid composition of the fat extracted with the chloroform-methanol mixture from the 3 batches analyzed and the physicochemical properties of the fat are shown in Table 3.

Fatty acid	%
Linoleic acid	58.85
Oleic acid	20.12
Palmitic acid	12.99
Stearic acid	4.13
Linolenic acid	2.63
Palmitoleic acid	0.41

Table 2. Fatty acid composition of tomato seed flour oil

Iodine value	130.72
Saponification index	185.12
Acidity index	0.16
Peroxide index (meq/Kg)	7.80
Density at 20°C (g/ml)	0.909
Refractive index at 20°C	1.475

Table 3. Chemical and physical properties of tomato seed oil

Regarding toxicological analyses, all batches gave negative results for trypsin inhibitors, phytohemagglutinins and saponins.

From the results of the functional properties, the oil absorption capacity gave a value of 138.75% of fat absorption. Regarding the emulsifying capacity, the foaming capacity and the stability of the foam, it is shown in Figures 1A, 1B and 1C.

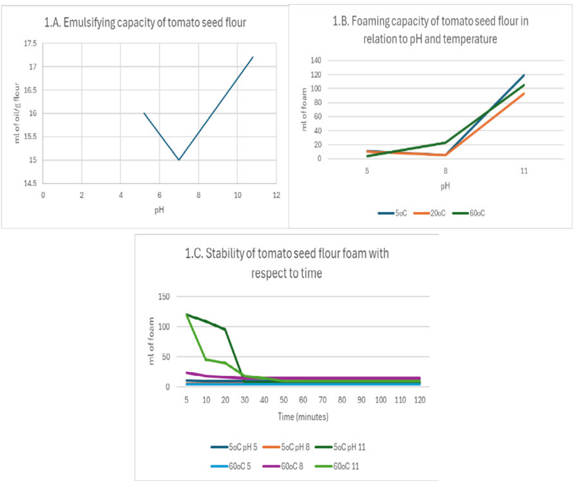

Figure 1. A shows the emulsifying capacity of tomato seed flour depending on the pH, B shows the foaming capacity of tomato seed flour with respect to pH and temperature, and C shows the stability of foam of tomato seed flour at different temperatures and pH respect to time.

DISCUSSION

With respect to the proximal analysis, Table 4 presents a comparison of the values obtained with respect to other studies; in general, high values of crude fat and protein are reported in almost all studies, as well as in total dietary fiber.

The differences in the values, especially of protein and crude fat, between our study and those shown in table 4 could be due to different reasons such as different cultivars and varieties of tomato (the lots of the present study mainly comprised the guaje, ball and ponderosa varieties), different growing conditions in each study and processing methods in which the amount of seeds, pulp and skin vary greatly in the waste byproduct. These differences are notable, for example in the work of Elbadrawi and Sello (2016), where they show results exclusively from the skins and very different results are observed from those of the rest of the researchers.

Considering that the main contribution of macronutrients from seeds lies in protein, fat and dietary fiber, further analysis was carried out on these macronutrients. In the case of proteins, the amino acid content and digestibility were analyzed. Table 5 shows the comparison of amino acids reported by various authors and the results obtained in our study. Tomato seeds were found to contain significant concentrations of essential amino acids, indicating that they contain high quality proteins with a high content of tryptophan, histidine and threonine which is very similar to the results obtained in other studies. The comparison of these data shows that tomato seed flour almost meets the FAO recommendations and is even superior in some amino acids to proteins such as those from beans and wheat (Mironeasa y Codina, 2019).

Regarding the amino acid lysine, the content, as indicated by other authors (Table 5), is in a good amount, covering practically 90% of the FAO recommendation. Consequently, several low-lysine food products that lack this amino acid may benefit from seed fortification. One of these products is bakery products that use wheat flour as a base ingredient because it contains less lysine. Taking whole egg protein as a reference, the chemical score calculation indicates valine as the limiting amino acid (chemical score 80.40).

Because lysine is often the first or second limiting amino acid in many foods (especially grain-based foods), and is susceptible to chemical modification during processing or cooking to form nutritionally unavailable derivatives, the amount of lysine biologically available dietary supplement is of extreme importance (Hurrell and Carpenter, 1981). Furthermore, it has been shown that lysine intake is usually marginal in low socioeconomic groups. In our study we determined that the amount of lysine available by the Hurrel and Carpenter method is 30.2 g/g protein, which still almost covers 60% of the FAO standard.

We do not calculate the PDCAAS in this work, because the method does not credit the extra nutritional value of high-quality proteins: since scores >100 are considered 100, the PDCAAS method does not credit the extra nutritional value of a protein that has a score higher than that of the reference protein, such as eggs, fish, milk and most meat protein products and overestimates protein quality of products containing antinutritional factors

Regarding the in vitro digestibility analysis, the result obtained was low (61.61%), however it must be considered that the technique used is affected by factors such as the high fiber content that gives results lower than the real value.

Regarding the fiber content, was high (average of 21%) and very similar to what was

Moisture	Ash	Crude Fat	Crude Protein	Total dietary fiber	Nitrogen-free extract*	Reference
6.47 (0.84)	4.1 (0.15)	40.5 (0.38)	30.0 (1.0)	21.8 (2.64)	3.6 (1.0)	Results in this work
7.4-9.6	3.0-3.1	20.1-19.9	25.5-25.0	33.9-36.3	-	Persia et al., 2003
11.33	3.16	20.0	31.66	35.5	-	Shammari, 2023
-	5.90	4.04	10.5	-	78.56	Elbadrawy & Sello, 2016 (just peels)
		27.1	31.6			Al-Wandawi, 1985
6.17	4.7	23.92	27.54	16.81	27.03	Kassab, 2007
-	5.3	26.7	29.2	22.1	16.7	Moharram et al., 1984

Table 4. Comparison of the proximal composition of the results of this work and other researchers

Amino acid	TSF	Al-Wandawi et al., 1985	Elbadrawy & Sello, 2016 (just peels)	Kassab, 2007	Shamari, 2023 (ug/g)	Persia et al., 2003 (%)
	mg/ g protein					
Methionine + Cysteine	24.9	21.8	1.41	15.2	48.9	0.87-0.71
Lysine	46.9	62.7	44.0	59.3	166.8	1.48-1.19
Isoleucine	30.7	34.5	38.6	51.6	55.9	1.04-0.89
Leucine	40.6	43.8	50.7	60.5	79.8	1.66-1.41
Histidine	26.2	62.9	36.4	26.7	159.5	0.61-0.49
Phenylalanine + Tyrosine	40.5	44.6	66.4	92.0	121.4	2.23-1.86
Valine	30.5	40.5	45.8	49.3	94.09	1.16-1.01
Threonine	43.0	64.8	23.4	34.5	-	0.90-0.73
Arginine	31.7	-	43.4	74.7	142.9	2.43-1.84
Tryptophan	9.70	-	-	-	136.0	-
Available lysine	30.2	-	-	-	-	-

Table 5. Comparison of the amino acid content of the protein from various studies, the FAO standard and the results obtained

*TSF tomato seed flour

found by other researchers as shown in table 4. According to García-Herrera et al (2010), the total fiber of tomato seeds is composed mainly of carbohydrates, with an average value of 80% of the total dietary fiber (much higher than that of other plant by-products), being the insoluble fiber the majority component, which could justify its use as a functional ingredient for the production of food ingredients with potential health-promoting effects. Considering the average fiber content of our tomato seed flour, its inclusion in low-fiber products could contribute to enriching the insoluble fiber content and thus improve fiber consumption in the population; supplementations of between 10 and 20% would be sufficient. to develop products high in fiber (6 g/100 g of product or 3 g/100 Kcal), which would be of great importance since, in Mexico, adults consume between 16 and 18 grams of fiber per day, a much higher amount. less than recommended (Secretaría de Salud, Mexico).

Table 2 shows the composition of the extracted fat expressed as a percentage of the fatty acid. These results reveal that the fat of tomato seed flour presents, like most vegetable oils, a high degree of unsaturation represented by linoleic acid (59.85%), a value comparable to that presented by corn oil (53%), sunflower (65%) or soybean (51%) which are some of the oils with the greatest commercial demand.

The results presented in Table 2 illustrate the fatty acids identified in tomato seed oil are linoleic acid (ω6) which represents the main fatty acid with a percentage of 59.85% of the total fatty acids followed by oleic acid (20.12 %), while linolenic acid (ω3) was 2.63% and palmitoleic acid was 0.41. The saturated fatty acids found in tomato seed oil were palmitic (12.99%) and stearic (4.13%) with a total percentage of 17.12%. The seed oil contains a high level of unsaturated fatty acids, especially linoleic acid (ω6) and linolenic acid (ω3), which are essential fatty acids that protect the body from cardiovascular risk (Elbadrawi, 2016).

Regarding the chemical and physical analyzes of fat, it is known that these serve as a basis for the identification of a given fat or oil for a defined purpose. Table 3 shows that tomato seed fat has a high iodine index, which reflects its high degree of unsaturation. Both the specific gravity and the refraction and saponification indices are comparable with vegetable oils such as corn and sunflower seeds. The low free acidity could represent an advantage at an industrial level during the refining process, while the peroxide index indicates that it is a recently extracted oil, without rancid flavors or odors, since these begin to form between 20 and 40 meq/Kg.

In relation to the toxicity of tomato, within the Solanaceae family this is given by alkaloids. The predominant glycoalkaloid in tomato is alpha tomatine, it is found in high concentration in the foliage and in the green fruit, however, as the fruit ripens, alfa tomatine degrades into inert components (even at large doses it is less toxic than the alkaloids of blackberry, nightshade and other species). In the literature, only a search for trypsin inhibitors, phytohemagglutinins and saponins has been reported with negative results, which were confirmed in the present investigation. In part, this could be due to the fact that we are talking about agroindustrial waste that has been subjected to high temperatures and a series of washings in water, which greatly reduces the possibility of finding thermolabile and/or water-soluble compounds in it. Regarding the bitter taste described for some products added with tomato seeds, it could be due to steroidal compounds that are easily separated by washing in hot water (Mironeasa & Codină, 2019).

Figures 1A, B and C show the functional properties of tomato seed flour. Tomato seed flour has an oil absorption capacity of 138.75 ml/g, which is high and very similar to that of soybeans. The emulsifying and foaming capabilities were tested at three different pH (acidic, neutral and alkaline), as shown in the figures. The emulsifying capacity proved to be high, which could imply its use in food emulsions such as creams, ice creams, etc., an additional advantage of this property was the good stability of the emulsion formed, which was approximately 80%, therefore, tomato seed flour could serve as a flavor retainer and improve the flavor and texture of foods (Lzidoro et al., 2023).

Regarding foam formation at pH 5 and 8, the volume of foam formed was only 10-15 ml, with foam formation at pH 11 having no practical interest, since no foods are found at this pH, although it is worth mentioning that the foam volume under these conditions reached more than 120 ml. It is also worth mentioning that the stability of the foam formed (Figure 1C) was very low, regardless of the temperature at which it was determined (5 and 60oC). After 60 minutes, the foam practically disappears in all the samples, however this could be because defatted tomato seed flour was used to carry out this test.

CONCLUSIONS

Fortunately, tomato waste, widely available in many developing countries, is a good source of primary nutrients. These tomato wastes have high contents of proteins, lipids and carbohydrates. Tomato seed flour has good nutritional value due to its content of essential amino acids and fatty acids in addition to its high content of total dietary fiber. Therefore, waste from tomato industrialization could be used as a value-added ingredient in other food products where it could play an important role in improving functional and nutritional properties, for example added to canned meats, food concentrates or baking.

Tomato seeds are a better source of protein than other non-conventional sources as they do not contain any anti-nutritional elements, unlike other seed sources. The inclusion of tomato seeds in the human diet can also help reduce environmental pollution problems and increase the added value of waste.

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