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TRANSITION AND SENSORY CHARACTERISTICS OF MEAT ANALOGUES BASED ON VEGETABLE PROTEINS WITH TOMATO POWDER, OBTAINED FROM TOMATO PROCESSING

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Abstract

The paper presents a preliminary study of the realization of meat analogues based on vegetable protein with tomato powder. The bibliographic study, a means of reference for the realization of the meat analogue based on vegetable proteins with tomato powder, led in the first step to the obtaining of the tomato powder and to the performing of its physicochemical characterization. Subsequently, the sensory properties of the newly manufactured meat analogues were characterized, which represented the transition to the first plant-based meat analogues enriched with olive powder obtained from the vegetation waters of olive mills, by using spray-drying technology. The results obtained opening up new opportunities for research, contributing to the sustainability of the environment and the circular economy.

Key words: *antioxidant activity, sensory analysis, sustainability, tomato powder.*

INTRODUCTION

Agriculture and the food industry are the most representative branches in Europe (Palvic et al., 2023), generating a major source of organic residues in the form of food waste (Raksasat et al., 2020). According to Zioga et al. (2022), the food sector is responsible for approximately 26% of global greenhouse gas emissions. Waste from the food industry causes pollution, with difficulties in managing and eliminating economic losses (Ilyas et al., 2021).

Improper waste management can have a relevant impact on the environment, which is why it is necessary to exploit alternative technologies for the recovery and exploitation of this waste, in order to obtain benefits for society (Srivastava et al., 2023).

International scientific research has focused on the characterization of fruit and vegetable by-products, and their subsequent incorporation for the development of functional foods (Trigo et al., 2020). Industrial residues from fruits and vegetables consist mainly of peel, pomace, and seed fractions, which contain compounds with high nutritional value, such as proteins, vitamins, minerals, polysaccharides, dietary fiber, flavoring substances, phytochemicals, and bioactive compounds such as flavonoids or lycopene (Galanakis, 2021).

By-products and residues are nutritionally rich food ingredients with special functional properties (Girotto et al., 2015). From an ecological perspective, sustainable foods must reconsider by-products from the food industry as a valuable source of antioxidants, fiber, etc. (Rodrigues-Lopez et al., 2020). Various studies have shown that residues obtained from fruits and vegetables processing have a high content of bioactive compounds with high antioxidant capacity (Fan et al., 2021) and a beneficial role on human health (Tlais et al., 2020).

Tomato residue is the by-product obtained during the technological process of tomato processing, consisting of a mixture of seeds, tissue and peels in a proportion varying between 40-60% (Zhang et al., 2015). Industrial processing of tomatoes generates large amounts of solid waste of organic nature, representing approximately 20-50 g/kg of the initial weight of tomatoes (Knoblich et al., 2005). The constituents of tomato by-products are carbohydrates, organic acids, fibers, proteins, oils and vitamins (Lu et al., 2019). The chemical composition of seeds and skins is significantly different; seeds contain high-

quality proteins such as lysine, skins are rich in carotenoids such as lycopene and beta-carotene, dietary fibers and phenolic compounds (De Malle et al., 2006; Sarkar et al., 2014).
The main bioactive constituent of tomato peels is lycopene, representing 85% of the total carotenoid content (Clinton et al., 1996), with lycopene concentration being three to five times higher in peels than in fresh fruit (Szabo et al., 2018). Fibers include both insoluble fibers such as lignin, cellulose and hemicelluloses, as well as soluble fibers such as pectins, β-glucans, galactomannan gums and a wide range of indigestible oligosaccharides, including inulin. Tomato by-products can be used as bioactive ingredients in the production of new foods (Garcia-Herrera et al., 2010).
The efficient recovery of agri-food waste and by-products aims to achieve a circular economy with minimal negative impact on the environment, with a positive effect on ensuring food security (Bhat et al., 2021).
The work is based on a laborious bibliographic study, with practical applications regarding the valorization of tomato residue (but also other residues), as well as the realization of numerous preliminary experiments for the creation of the meat analog with tomato powder, which represented the starting point in the creation of further meat analog containing olive powder by-product obtained from the vegetation waters of olive mills, using spray-drying technology.

MATERIALS AND METHODS

1. Reagents & Materials

The physicochemical characterization of tomato residue and tomato powder, as well as preliminary experimental research on obtaining the meat analogue based on vegetable proteins, were carried out in the laboratory of the Faculty of Biotechnology, within the University of Agronomic Sciences and Veterinary Medicine, Bucharest. To make the meat analogue, tomatoes cultivated by the producer (S.C Grădina Doamnei S.R.L., from Dâmbovița, Romania), the meal resulting from obtaining pumpkin oil (S.C Grădina Doamnei S.R.L., from Dâmbovița, Romania) were used. The mushrooms, lentils and spices were purchased from a market in Târgoviște Municipality, Dâmbovița, Romania.
Reagents used: pure methanol (CH_3OH), DPPH solution (1:10 dilution), methanol (80:20 methanol: distilled water ratio), nitrogen (N_2), Folin-Ciocâlteu reagent, sodium carbonate (Na_2CO_3), distilled water, as well as laboratory objects (aluminum capsules for humidity determination, test tubes, micropipettes, eppendorf, volumetric flask, graduated cylinder).

2. Tomato by-product & Tomato Powder

a. Obtaining the Tomato Powder

Tomato by-product resulted during tomato processing, by applying the general technological scheme for obtaining tomato juice, within S.C. Grădina Doamnei S.R.L., from Dâmbovița, according to Figures 1 and 2.

Figure 1. Freshly obtained tomato by-product.

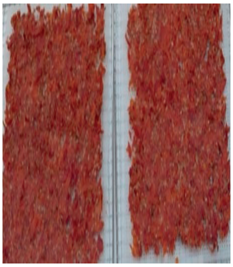

Figure 2. Tomato by-product before heat treatment

The dehydrated tomato by-product was obtained according to the author's description (Manea, 2017) with some modifications. The freshly obtained tomato by-product was dried at 35°C± 2°C for 48 hours, using a dehydration chamber, according to Figures 3, 4.

Figure 3. Dehydration chamber

Figure 4. Dehydrated tomato by-product

The dehydrated tomato by-product was ground with an electric mixer, according to Figure 5, and the tomato powder was stored in a vacuum package, according to Figure 6, protected from sunlight and heat, until the meat analogue was manufactured.

Figure 5. Electric stirrer

Figure 6. Packaged tomato powder

b. Determination of tomato powder moisture

The moisture content of tomato powder was determined according to the method described in ISO (662:1998), adapted to laboratory conditions (using a thermobalance), according to Figure 7. The method consisted of taking ±2 g of the sample from the powder obtained from the tomato residue, which was distributed homogeneously and in a thin layer on the weighing pan, in order to obtain reproducible results.

Figure 7. Closed thermobalance

c. Determination of total phenolic content in the extract obtained from dried tomato by-product

The determination of total phenolic content was performed according to the authors' description (Munteanu et al., 2021). The Folin-Ciocâlteu test aims to determine the total phenol content of foods and plant extracts, and is based on the reduction of the Folin-Ciocâlteu reagent with phenolic compounds in an alkaline state.

200 µL of extract sample was left in the test tube, to which 1800 µL of distilled water was added. Next, 10 ml of Folin-Ciocâlteu reagent and 8 ml of sodium carbonate (Na_2CO_3) were added.

Control sample: 2000 µL of distilled water, plus 10 ml of Folin-Ciocâlteu reagent and 8 ml of sodium carbonate (Na_2CO_3). Cover the tubes with microfilm, shake and leave to stand for 2 hours before reading on the UV spectrophotometer.

3. Manufacturing the meat analogue with tomato powder

A comprehensive bibliographic study on the current state of knowledge regarding the valorization of residues and by-products from the food industry, as well as the current state of knowledge regarding meat analogues, preliminary research aimed at studying labels regarding the composition of meat sausages, but also numerous preliminary experimental research on obtaining analogues, have led to the experimental realization of the meat analogue with tomato powder, under laboratory conditions, according to Figure 8.

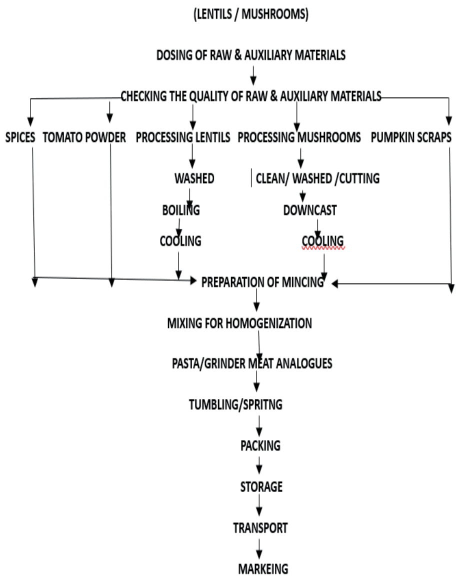

Figure 8. Technological scheme for obtaining meat analogue (raw) based on lentils/mushrooms with tomato powder

The meat analogue with tomato powder was made in the laboratory of the Faculty of Biotechnology, within the University of Agronomic Sciences and Veterinary Medicine in Bucharest. After multiple preliminary experiments, a paste was obtained, according to Figure 9 and an initial raw product, according to Figure 10.

Figure 9. Lentil/mushroom meat analogue paste with tomato powder

Figure 10. Lentil/mushroom meat analogue with tomato powder

The obtained meat analogue based on lentils-mushrooms with tomato powder was tested when applying heat treatments (frying) according to Figure 11, resulting in the preliminary product in Figure 12, but was also tested when applying heat treatment (boiling).

Figure 11. The meat analogue with tomato powder subjected to heat treatment

Figure 12. The meat analogue with tomato powder after applying heat treatment

a. Determination of the moisture content of the meat analogue with tomato powder

The moisture content of the meat analogues with tomato powder was determined according to method B described in ISO (662:1998). The method was adapted to laboratory conditions, namely the use of a thermobalance. The moisture content of the lentil-mushroom meat analogues with tomato powder (raw) was determined at two-time intervals (T0-initial moment and T4-after four days).

b. Antioxidant activity of the meat analogue with tomato powder after applying heat treatment at the time interval T0 and T4

The determination of the antioxidant activity of phenolic compounds in the aqueous extract obtained from 5g of fresh tomato powder meat analogue was carried out according to the authors' description Munteanu et al., (2021), adapted to the specific conditions.

Practically, the antioxidant activity of phenolic compounds in the obtained extract was determined by the UV spectrophotometric method, respectively the DPPH test, according to Figure13.

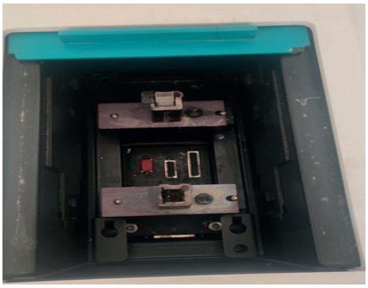

Figure13. Space for inserting cuvettes into the UV spectrophotometer

4. Sensory analysis of the meat analogue before/after heat treatment

The sensory analysis of the meat analogue based on lentils-mushrooms with tomato powder was carried out by referring to (Standardization, 1988), with some modifications.

Nine people (without training in the food industry) participated in the sensory analysis, the following characteristics were evaluated: external appearance, cross-sectional appearance, taste, smell and consistency. In the sensory assessment, the range of 2.50-3.50 points represented the average level of appreciation, less than 2.50 points-unsatisfactory product, score higher than 3.50 points-satisfactory product (the taste of the raw meat analogue was not evaluated).

RESULTS AND DISCUSSIONS

The sensory analysis of the lentil-mushroom-based meat analogue with tomato powder aimed at evaluating the following sensory attributes: external appearance, cross-sectional appearance, smell, taste and consistency of the analogue, using a scoring scale from 1 to 5, according to Table 1.

Table 1. Sensory attributes analyzed of the meat analogue with tomato powder

No. of points	Exterior appearance	Section view	Smell	Taste	Consistency
5	Like very much	Very good homogenous	Like very much	Like very much	Very good
4	Like	Good Homogenous	Like	Like	Good
3	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
2	Dislike	Dislike	Dislike	Dislike	Dislike
1	Unacceptable	Unacceptable / non-homogenized	Unacceptable	Unacceptable	Unacceptable

Source: Martin -Miguelez et al, 2024.

Tomato Residue & Tomato Powder

The **moisture content** of the tomato powder was 39.73± 0.37 (%) (The result is the average of two determinations).

The determination of total phenols was performed according to the authors' description Munteanu et al. (2021).

The phenolic characterization of the obtained tomato powder shows a rich content in polyphenols, the result of total phenols being expressed according to Table 2

Table 2. Total phenolic content of tomato powder

Determination of total phenolic content		
Sample	mg/kg	mg/kg s.u
Tomato powder	**608.61±0.03**	**1009.80±0.03**

The data are the mean value of two different analysis ± standard deviation. Legend: s.u.- dry matter.

Meat analogue with tomato powder

The **moisture content** of the (raw) meat analogues with tomato powder was determined at different intervals (T0 and T4), using the method described in ISO (662:1998) under specific conditions. The meat analogue sample was distributed on the surface of the weighing pan (± 2 g) and kept at a temperature of 103±2°C, until the volatile substances evaporated to obtain reproducible results, according to Figure 14.

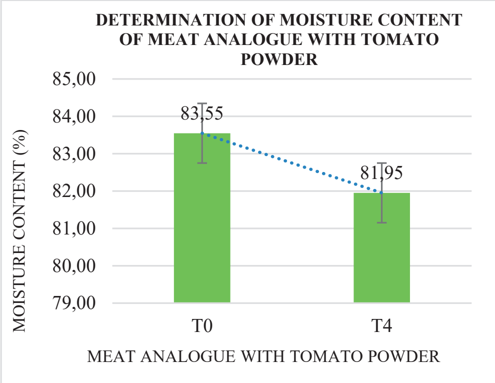

Figure 14. Determination of moisture content of meat analogues with tomato powder at time intervals T0 and T4

Antioxidant activity of meat analogues with tomato powder after applying heat treatment at time intervals T0 and T4

The antioxidant activity of the freshly prepared tomato powder meat analogue was determined after the application of heat treatment (time T0). The freshly prepared tomato powder analogue was stored in the refrigerator at 4°C and was thermally prepared after four days for the determination of antioxidant activity at time T4. The antioxidant activity of phenolic compounds from the extract obtained from meat analogues with tomato powder, subjected to heat treatment of frying, was carried out at two intervals time (T0 and T4).

DPPH reading was done with a UV spectrophotometer at wavelength λ=515nm.The result obtained are present according to Figure 15.

According to Figure 15 it can be observed that the antioxidant activity of the meat analogue with tomato powder (after applying heat treatment) increases at time T4 compared to the antioxidant activity of the meat analogue with tomato powder at time T0. The variability of the data at T0 and T4 could be due to the particle size and homogeneity of the raw material and the entire sausage paste, which is a common characteristic in this type of food. Taking into account the fact that the colorimetric method used is influenced by the reaction of the protein with the Folin-Ciocâlteu reagent (Everete et al., 2010).

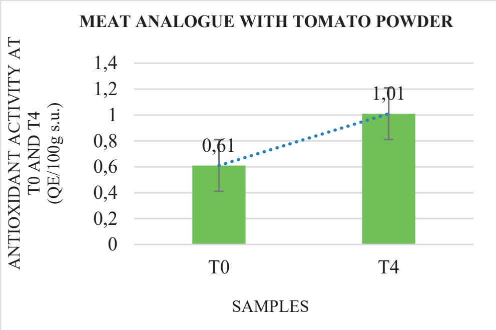

Figure 15. Antioxidant activity of the meat analogue with tomato powder, after applying heat treatment at time T0 and T4

Sensory analysis of the meat analogue before/ after the application of heat treatment

The sensory characteristics of the meat analogues with tomato powder, before/after the application of heat treatment are presented in Figures 16 and 17.

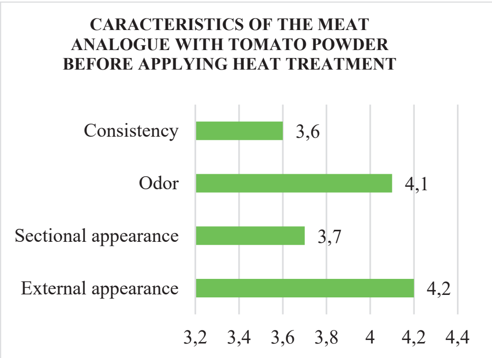

Figure 16. Sensory attributes of the meat analogue with tomato powder before heat treatment

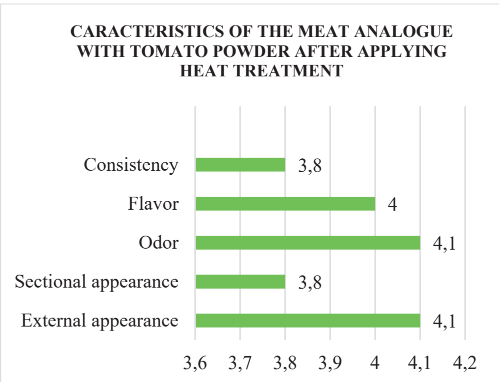

Figure 17. Sensory attributes of the meat analogue with tomato powder before heat treatment

CONCLUSIONS

Agriculture and the food industry are the main branches of the global economy, but improper management can lead to the generation of significant amounts of waste, which can affect the quality of human life, as well as the environment.

This work focuses on obtaining tomato powder, starting from the raw material (tomatoes), obtaining tomato juice and using the tomato residue to obtain tomato powder, as well as integrating the latter into a new food matrix. This approach contributes to obtaining new foods, which support environmental sustainability through zero waste, contributing to the circular economy. Applying efficient management throughout the technological process, regardless of the food sector or the technological process applied, involves the valorization of the resulting by-products and residues, thus contributing to reducing pollution, to the creation of "friendly" foods for humans and the environment, as well as the circular economy development. During the processing of plant products, a large amount of residues (seeds, peels, stalks, tissue) results, rich in bioactive compounds and with high nutritional value. Efficient recovery, as well as finding innovative solutions can contribute to opening new research horizons. Lentil-mushroom-based meat analogues with tomato powder are an alternative, which supports environmental sustainability, circular economy, by recovering tomato residue with zero waste and creating a "friendly" product for humans. The sensory attributes of the meat analogue with tomato powder open up research perspectives. Obtaining the meat analogue with tomato powder raises technological challenges in two key points (tube-forming operation, applied thermal process), and innovative solutions or alternative manufacturing solutions are needed to overcome the impediments. Technological progress and innovative ideas make it possible to develop meat analogues rich in bioactive compounds, with sensory and nutritional qualities, which can contribute to the development of the range of "human-friendly" products, as a sign of respect for Planet Earth.

Research on the meat analogue with tomato powder paved the way for the creation of the further validated meat analogue containing crude phenolic concentrate (olive powder) obtained from olive mill waste water, using spray-drying technology.

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