Original Scientific Paper

QUALITY PROPERTIES OF CHOCOLATE-COVERED DRIED PLUMS

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ABSTRACT

The demand for functional confectionery products is continuously increasing due to growing consumer awareness of their health benefits. The aim of this research was to evaluate the technological, nutritional and sensory properties of dried plums coated with dark, milk and white chocolate. *Stanley* variety plums, harvested at technological ripeness from the Berovo region, were analyzed as fresh fruit and then processed into dried plums and chocolate covered dried products. Standard laboratory methods were used to determine moisture content, total dry matter, total acids, total sugars, L-ascorbic acid, total ash and dietary fiber. Sensory evaluation was performed by assessing appearance, taste, aroma, and texture. Drying method significantly increased the concentration of nutritional ingredients and the shelf life of the product. Compared to fresh fruit, dried plums had higher total dry matter (73.40 %), sugars (43.35 %), total acids (1.33 %), vitamin C (20.29 mg/100 g), total ash (2.77 %) and dietary fiber (3.09 %). The average fruit mass was 28.27 g with a yield of 92.41 %. Sensory scores showed that all chocolate coated samples were well accepted, where the dark chocolate coated samples achieving the highest scores across most attributes, especially aroma, taste and texture. The results highlight that chocolate covered dried plums, particularly those coated in dark chocolate, offer a promising direction for developing nutritionally valuable, functional desert products. This combination meets consumer demands for food products that balance health benefits with sensory appeal.

Key words*:* chocolate, coating, dried, plums, quality.

INTRODUCTION

The development of novel product with nutritious ingredients has an effective role in improving diet quality. Consumption of fruit-based products increases the intake of nutrients and phytochemicals, which leads to positive health effects (Ostrowska-Ligęza et al., 2022**).** Chocolate-covered dried plums represent an innovative food product that combines the nutritional benefits of dried plums - rich in dietary fiber, antioxidants and vitamins - with the bioactive compounds of chocolate, such as polyphenols and flavonoids. This product offers a balance between health and satisfaction, in accordance with current trends in functional food development.

The plum (*Prunus domestica* L.) or European domestic plum, is a fruit species derived from the crossbreeding of *Prunus spinosa* (blackthorn) and *Prunus cerasifera* (cherry plum) (Veličković, 2002). Today, it represents one of the most important fruit crops in Europe, valued

both for fresh consumption and as a raw material for industrial processing. Plums are recognized for their role in digestive health. Therefore, increasing consumer demand for functional foods, plum-derived products offer significant market potential.

In the Republic of North Macedonia, plum cultivation holds great agricultural significance, ranking second among fruit crops after apples in terms of the number of trees and total production (MZSV, 2006). In 2024, plum production in North Macedonia reached 28.750 tons, with an estimated average yield of 18 kg per tree and a total of over 1.6 million plum trees, according to the State Statistical Office (https://makstat.stat.gov mk/PXWeb/pxweb/mk/, 14.04.2025). This positions plums as a cornerstone of the country's fruit sector, contributing significantly to rural economies and smallholder livelihoods.

High-quality plum fruits are classified as extra class and are intended for fresh consumption, achieving high prices in both domestic and international markets. The other classes of plum fruits are used for industrial processing, including marmalade, jam, frozen, dried and strong alcoholic beverages. According to Vlahović (2003), plum fruits are mostly used for the production of plum rakija (about 65 %), for fresh consumption about 8 %, for the production of dried plums about 4 %, for the production of jam under 2 % and for other plum products 21 % is used.

Plums are highly perishable, with rapid loss of firmness, acidity, and weight during storage. Controlled atmosphere storage and cold-chain logistics are essential to extend shelf life. Plums fruits at technological phase of ripeness, typically contain 16 – 18 % sugars and approximately 1.2 % total acids (Nikićević & Tešević, 2010). Despite their low caloric value, plums are rich in essential nutrients, including vitamins, minerals, carbohydrates and phytochemicals such as phenolic acids, anthocyanins, carotenoids and pectin's (Birwal et al., 2017; Neamțu et al., 2024). The sensory properties of plum fruits are determined by the content of sugar, organic acids, tannins, aromatic substances, anthocyanins and other compounds. Ripe fruits are a valuable energy source in the diet and possess both dietary and therapeutic properties (Veličković 2002; Walkowiak-Tomczak et al., 2008, Karakashova i sar., 2020).

In North Macedonia, commercial dried plum production is primarily based on the *stanley* variety, accounting for 80 – 85 % of plum orchards in major production regions such as Delčevo and Berovo, and around 60 % in Radoviš and Strumica (Dimitrov i sor., 2020). This variety is favored for its high dry matter content, balanced sugar-to-acid ratio, and firm fruit texture, making it particularly suitable for drying and long-term storage.

Drying is among the oldest and most effective preservation techniques, reducing water activity and thereby inhibiting microbial growth while maintaining flavor, nutritional value, and extending shelf life (Deak & Füstös, 2009; Mitrović, 2012). It ensures year-round availability of plums, especially during off-season periods when fresh fruit is scarce. Compared to fresh plums, dried plums have a longer shelf life, higher energy value and are considered a convenient and healthy snack.

Modern research emphasizes that industrial optimization of drying technologies must balance energy efficiency, product safety, and bioactive compound retention (Menon et al., 2020). When selecting plum varieties for drying, several factors - such as dry matter content, antioxidant levels, physical properties and texture - must be evaluated. Varieties with >20 % dry matter are preferred, as they reduce drying time and energy costs. Ideal varieties exhibit a favorable sugar-to-acid ratio and firm fruit texture, which prevents crystallization and enhances flavor and stability during storage (Vakula et al., 2020). Factors influencing drying efficiency include air temperature, humidity and airflow speed. Optimal range 55–65 °C; higher temperatures accelerate drying but risk nutrient loss. Lower humidity enhances drying speed; excessive humidity prolongs drying and risks microbial growth. Uniform airflow prevents case hardening and ensures consistent moisture removal (Sivakov & Karakashova, 2007).

Chocolates and chocolate products are favored by many people, especially children. As the global demand for healthy, fruit-based snacks continues to grow, chocolate-covered products have become particularly appealing due to their combination of health benefits and sensory attractiveness. These products typically contain nuts, fruit pieces or dried fruit coated with chocolate, offering a favorable balance of natural sugars, dietary fiber, antioxidants and fats (Komes et al., 2013; Tylewicz et al., 2020; Żyżelewicz et al., 2021; Ostrowska-Ligęza et al., 2022).

The chocolate panned products represent a type of food product exhibiting high storage stability. Preservation of high-quality food products during their storage requires monitoring such parameters as the temperature, air humidity, oxygen content in the storage room, as well as the proximate chemical compositions of the products. Also, the packaging type directly affects product shelf life and quality - especially lipid oxidation and moisture content (Nattress et al., 2004; Steele, 2004; Kłoczko et al., 2010; Nightingale et al., 2012; Ostrowska-Ligęza et al., 2022).

Numerous studies suggest that moderate consumption of cocoa products, especially dark chocolate, may provide various health benefits, such as reduced inflammation, improved cardiovascular health, lower blood pressure, better lipid profiles and reduced symptoms of depression and anxiety (Di Giuseppe et al., 2008; Yuan et al., 2017; Ren et al., 2019; Jafarnejad et al., 2020; Darand et al., 2021; Fusar-Poli et al., 2022).

Combining dried plums with chocolate merges the best of traditional fruit preservation with modern functional food innovation. This fusion results in a nutritionally valuable and sensorily appealing product that responds to consumer demand for healthier confectionery options.

In this research, the technological, nutritional and sensory properties of fresh and dried plums coated with different types of chocolate (dark, milk and white) were evaluated, using the *stanley* variety as raw material. The aim was to assess how the drying process and chocolate coating affect the quality characteristics of the final product, in order to develop a nutritious and sensorially appealing functional snack.

MATERIALS AND METHODS

For the purposes of this research, the fruits of the *stanley* plum variety were used, harvested from orchards in the Berovo region, Republic of North Macedonia. The *stanley* variety is one of the most widely cultivated plum cultivars globally, present in many European countries and originates from the USA. It is a moderately vigorous variety with a broad pyramidal canopy. The fruits are medium to large (approximately 23 - 37 g), oval to slightly oblong in shape. The epidermis is dark violet, with a characteristic gray waxy bloom, which provides natural protection against desiccation and microbial colonization. The mesocarp is greenish-yellow, firm, juicy and easily separable from the stone, a trait favorable for processing. The variety typically ripens in the second half of August and early September, depending on the growing location and conditions. It tolerates well transportation, unless it is overripe and is suitable for different processing methods (Mišić, 1979; Niketić-Aleksić, 1994; Veličković, 2002).

Fruits of the *stanley* plum (*Prunus domestica* L.) variety were hand-picked at the stage of technological maturity, characterized by a uniform dark violet exocarp color and a distinct waxy bloom, indicating optimal ripeness. Selective harvesting was performed to ensure uniformity in fruit size, shape, and maturity stage, minimizing variability in subsequent analyses. Both fresh and dried plums were analyzed to compare their chemical composition and to identify changes resulting from the drying process.

A total of 30 fresh fruits of plums were selected randomly for pomological analysis. The following parameters were analyzed: fruit dimensions (length, width and thickness), fruit and

stone mass and fruit yield (%), calculated as the proportion of the mesocarp mass relative to the total fruit mass. Length, width and thickness of the fruit were measured with a manual caliper with a precision of ± 0.01 mm and the results were expressed as average values. Fruit and stone mass were determined by using an analytical balance ("Sartorius") with a precision of ± 0.01 g.

Following harvest, the fruits were transported under controlled conditions (ambient temperature 18–20 °C, relative humidity 65–70%) to a processing facility, where they underwent a series of operations as part of the drying process. These included the purchase of raw material, inspection, washing, calibration (grading by size), stone removal, drying (hot-air convection drying), packaging in polyethylene bags and stored at 4 °C.

Before the drying process, an analysis of the fresh *stanley* plums was performed to evaluate the quality of the raw material intended for the production of a high-quality final product. Both fresh and dried plums were subjected to chemical analyses, using standard laboratory methods to evaluate compositional changes during drying:

- moisture content using a digital moisture analyzer;
- total dry matter using gravimetric analysis by drying the material in a laboratory oven at 105 °C until constant weight;
- total acids (expressed as malic acid) using titrimetric analysis with 0.1 M NaOH and 1 % phenolphthalein as indicator;
- total sugars (fructose, glucose, sucrose) determined by High-Performance Liquid Chromatography (HPLC) with a Refractive Index (RI) detector;
- L-ascorbic acid (Vitamin C) using iodometric titration with 0.1 N iodine solution and 1 % starch as indicator;
- total ash (mineral content) using gravimetric analysis by incineration at 525 ± 25 °C;
- dietary fiber content determined by gravimetric analysis using medium filtration.

After the initial chemical characterization of fresh *stanley* plums, fruits were processed into dried plums using a tunnel dryer (industrial-scale, hot-air convection system), located at a private fruit processing facility. Drying was conducted at 65–70 °C with controlled airflow (1.5–2.0 m/s) until the final moisture content reached < 25 %, ensuring extended shelf life and reduced microbial activity. The drying kinetics were monitored by periodic weighing of samples to determine moisture loss curves.

The chocolate-coating of the dried plums was performed under laboratory conditions. Part of the dried plum sample was further processed and coated with chocolate (dark, milk, or white), in order to produce a final product with enhanced sensory and nutritional properties. The chocolate-covered dried plums were not subjected to further thermal treatment, since the drying process itself already significantly reduced water activity, inhibiting microbial growth.

The final chocolate-covered dried plums underwent sensory evaluation to assess their attractiveness to consumers in terms of taste, smell, texture, color, aroma and overall impression. The sensory analysis was performed using a 20-point scoring system (Karakashova & Babanovska-Milenkovska, 2012).

To determine the quality of dried plums, parameters defined by national food regulations and legal standards of the Republic of North Macedonia were applied.

All chemical and sensory analyses were performed at the laboratories of the Faculty of Agricultural Sciences and Food – Skopje, and at the Public Health Center – Kumanovo. The obtained results were statistically analyzed and interpreted in order to draw conclusions that may be relevant for wider application in the food industry. The obtained results were statistically processed.

RESULTS AND DISCUSSION

Morphometric characteristics of fresh plum fruits

Morphometric evaluation of fresh plum fruits of the (*Prunus domestica* L.) of the *stanley* variety revealed that this cultivar is characterized by medium to large fruit size. The average fruit mass was 28.27 g, while the average stone mass was 2.14 g, corresponding to a calculated fruit yield of 92.41 %. These values indicate a favorable flesh-to-stone ratio, which is an important trait for both consumer preference and industrial processing.

In terms of dimensional parameters, the Stanley fruits exhibited mean values of 45.81 mm in length, 33.36 mm in width, and 33.15 mm in thickness. Such dimensions place the *stanley* variety within the category of cultivars suitable for fresh consumption as well as for technological processing, given the balance between fruit size, mesocarp yield, and uniformity.

The morphometric profile presented in Table 1 provides quantitative confirmation of the cultivar's suitability for diverse applications, highlighting its potential for both fresh market distribution and value-added processing.

Table 1. Morphometric characteristics of fresh plum fruits, *stanley* variety

	Plum mass	**Stone mass (g)**	**Length (mm)**	**Width (mm)**	**Thickness (mm)**	**Yield (%)**
Mean ($\bar{X}$)	28.27	2.14	45.81	33.36	33.15	92.41
Standard deviation (SD)	3.37	0.28	2.90	1.76	1.31	0.67
Minimum	23.22	1.69	39.50	29.60	30.00	90.91
Maximum	37.38	2.97	52.40	36.50	35.40	93.98

Quality and nutritional properties of fresh and dried plum fruits

To estimate the quality and nutritional properties of fresh and dried plum fruits, analyses were performed on some physico-chemical parameters. The results of comparative analysis of physico-chemical parameters in fresh and dried plum fruits, *stanley* variety is presented in Table 2. The data demonstrate significant compositional changes induced by the drying process.

Table 2. Quality and nutritional properties of fresh and dried plum fruits of the *stanley* variety

Plum fruits	**Fresh fruit**	**Dried fruit**
Moisture content (%)	**73.87**	26.60
Total dry matters (%)	26.13	**73.40**
Total acids (%)	0.49	**1.33**
Total sugars (%)	10.54	**43.35**
L-ascorbic acid	3.30	**20.29**
(mg/100 g)	0.50	**2.77**
Total ash (%)	0.72	**3.09**
Dietary fiber (%)		

The moisture content of fresh fruits was 73.87 %, which markedly decreased to 26.60 % in dried fruits, reflecting the efficiency of the dehydration process. This reduction in water

content corresponded to a substantial increase in total dry matter, rising from 26.13 % in fresh fruits to 73.40 % in dried samples.

The total acid content exhibited a notable increase during drying, from 0.49 % in fresh fruits to 1.33 % in dried fruits, likely due to the concentration effect as water was removed. A similar trend was observed for total sugars, which increased from 10.54 % to 43.35 %, enhancing the sweetness and energy values of the dried product.

The concentration of L-ascorbic acid (vitamin C) was higher in dried fruits (20.29 mg/100 g) compared to fresh fruits (3.30 mg/100 g), suggesting either a concentration effect or potential analytical variability due to matrix changes during drying.

The ash content, indicative of total mineral matter, increased from 0.50 % in fresh fruits to 2.77 % in dried fruits, while dietary fiber content rose from 0.72 % to 3.09 %, further supporting the nutritional enrichment of the dried product.

These findings underscore the profound impact of drying on the chemical composition of plum fruits, with implications for both nutritional value and functional properties. Variations in reported values across different studies may be attributed to a range of factors, including agroecological conditions (e.g., soil type, climate), cultivation practices, irrigation regimes, and postharvest handling techniques, all of which can influence the biochemical profile of plum fruits.

Sensory evaluation of the chocolate-covered plum fruits

A sensory analysis was conducted to assess the sensorial properties of dried plum fruits, *stanley* variety, coated with three types of chocolate: dark (Sample 1), milk (Sample 2), and white (Sample 3). The evaluation was performed at the Laboratory for processing fruits and vegetables, Faculty of agricultural sciences and food - Skopje, by a trained panel of expert assessors with experience in sensory profiling of fruit-based products.

The sensory properties evaluation included assessing of: color, aroma, taste, and texture, using a structured scoring system with a maximum of 20 points per sample. Each sensory property was rated with a maximum number of points: color (7 points), aroma (4 points), taste (5 points), and texture (5 points). The results of the evaluation are presented in Table 3.

Table 3. Sensory evaluation scores for the color, aroma, taste and texture of chocolate-covered dried plums

	Sample 1	**Sample 2**	**Sample 3**
Color (max. 7)	6.60	**6.70**	5.80
Aroma (max. 4)	**3.57**	3.47	2.82
Taste (max. 5)	**3.78**	3.44	2.88
Texture (max. 5)	**4.21**	3.95	3.60
Total (max. 20)	**18.16**	17.56	15.1

According to the presented data at the Table 3, the following can be stated: for colour, the highest average score was recorded for Sample 2 (milk chocolate), with 6.70 points, indicating a visually appealing appearance. Sample 1 (dark chocolate) followed closely with 6.60 points, while Sample 3 (white chocolate) received the lowest score (5.80 points), possibly due to lower contrast or less favorable visual integration with the dried plum matrix; for smell (aroma), the Sample 1 exhibited the most favorable aromatic profile, achieving an average score of 3.57 points, followed by Sample 2 (3.47 points) and Sample 3 (2.82 points). The superior aroma of Sample 1 may be attributed to the intense volatile compound's characteristic of dark chocolate, which synergize well with the based aroma of dried plum; for taste, the

highest score was again observed in Sample 1 (3.78 points), suggesting a well-balanced flavor profile between the bitterness of dark chocolate and the natural sweetness of the dried plum. Sample 2 scored 3.44 points, while Sample 3 received the lowest score (2.88 points), potentially due to excessive sweetness or lack of flavor complexity; for texture, the Sample 1 also led in textural quality, with an average score of 4.21 points, indicating a desirable mouthfeel and structural integrity. Sample 2 followed with 3.95 points, and Sample 3 scored 3.60 points, possibly reflecting differences in chocolate viscosity, mouth melting sensation, or coating thickness.

Based on all above, the Sample 1 (dark chocolate-coated dried plums) demonstrated the most favorable sensory profile across aroma, taste, and texture, while Sample 2 (milk chocolate) was preferred in terms of colour. Sample 3 (white chocolate) consistently received the lowest scores across all evaluated parameters, suggesting limited sensory compatibility with the dried plum matrix.

These findings highlight the importance of chocolate type in modulating the sensory appeal of chocolate-covered dried fruits and provide valuable guidance for product development targeting consumer preferences.

CONCLUSION

The present study provides comprehensive evidence that chocolate-covered dried plums obtained from the plum fruits (*Prunus domestica* L.), *stanley* variety, constitute a nutritionally enriched and sensorially appealing product with significant potential in the processing fruit sector, as a functional food. The plum fruits, *stanley* variety, used as the raw material, was characterized by medium to large fruits with an average fruit mass of 28.27 g, a stone mass of 2.14 g, and a notably high fruit yield of 92.41 %, confirming its suitability for both fresh consumption and technological processing. The morphometric parameters (length, width, and thickness) further support the cultivar's favorable physical attributes for drying and other processing applications.

The drying process induced profound compositional changes, reducing the moisture content from 73.87 % in fresh fruits to 26.60 % in dried fruits. This dehydration led to a concentration of essential nutrients, reflected in the elevated values of total dry matter (73.40 %), total sugars (43.35 %), total acids (1.33 %), L-ascorbic acid (20.29 mg/100 g), total ash (2.77 %), and dietary fiber (3.09 %). Such modifications not only enhance the nutritional value of the dried product but also contribute to improved shelf stability and functional properties, positioning dried plums *stanley* variety as a valuable raw material for healthy oriented food innovations.

The sensory evaluation of chocolate-coated dried plums revealed that the addition of chocolate significantly improved consumer-relevant properties, particularly in terms of flavor complexity and textural appeal. Among the three tested chocolate-coatings, with dark (Sample 1), milk (Sample 2), and white (Sample 3), all samples were generally well accepted, yet clear differences emerged in preference. Sample 1 (dark chocolate) achieved the highest overall sensory score (17.92/20), consistently outperforming the other samples in smell (aroma), taste and texture, thereby demonstrating a strong compatibility between the intense flavor profile of dark chocolate and the concentrated sweetness and acidity of dried plums. Sample 2 (milk chocolate) was rated highest for color (6.70/7.00) and achieved a competitive overall score (17.43/20), while Sample 3 (white chocolate) received the lowest evaluations (14.85/20) across most attributes, suggesting limited sensory synergy with the dried plum matrix.

Based on these findings, it can be concluded that dried plums of the *stanley* variety, particularly when coated with dark chocolate, represent a promising product for the functional food market. Their rich nutrient content, extended shelf life, and high sensory quality make

them an excellent candidate for healthy snack development. Future research may focus on optimizing production parameters, extending shelf-life studies, and conducting broader consumer preference testing to support large-scale commercialization of this innovative product.

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