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Biochemical characteristics of plum (*Prunus domestica L.*) fruits and assessment of their suitability for different processed products

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Биохимические характеристики плодов сливы (*Prunus domestica L.*) и оценка их пригодности для различных переработанных продуктов

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Abstract

The biochemical composition of fruits determines both their nutritional value and the technological behaviour of the raw material during processing. The present study evaluated six plum (Prunus domestica L.) cultivars — Ispolinskaya (control), Black Diamond, Kirgizskaya Prevoskhodnaya, Monfort, Chernosliv Samarkandskiy and Yutuq — grown under the conditions of Uzbekistan over five consecutive seasons (2021–2025), with the aim of assigning each cultivar to a specific processing direction: candied fruit, marmalade or pastille. Dry matter, total soluble solids, titratable acidity and pectin substances were determined by standard methods, the sugar–acid ratio was calculated, and sensory properties were scored on a five-point scale by a seven-member panel. Dry matter ranged from 18.44±0.52 to 23.62±0.78 %, total soluble solids from 16.64±1.35 to 20.54±0.84 °Bx, titratable acidity from 0.47±0.04 to 0.73±0.06 %, and pectin from 0.66±0.02 to

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1.09±0.03 %. Chernosliv Samarkandskiy accumulated the highest dry matter, soluble solids and pectin contents, whereas the highest sugar–acid ratio (35.8) was recorded in Black Diamond. Analysis of between-season variability showed that titratable acidity was the most season-dependent parameter (CV 8.2–10.1 %), with maximum values in all six cultivars occurring in the same season (2022), while pectin accumulation proved to be a stable cultivar-specific trait (CV 2.9–3.6 %) and can therefore be used as a reliable criterion when allocating raw material to gel-type products. Overall sensory scores ranged from 4.2 to 4.8 points. Monfort and Chernosliv Samarkandskiy are recommended for candied fruit production, and Chernosliv Samarkandskiy and Kirgizskaya Prevoskhodnaya for marmalade and pastille manufacturing.

Аннотация

Биохимический состав плодов определяет как их пищевую ценность, так и технологическое поведение сырья в процессе переработки. В статье приведены результаты пятилетних (2021–2025 гг.) исследований шести сортов сливы (Prunus domestica L.) — Исполинская (контроль), Блек Даймонд, Киргизская превосходная, Монфор, Чернослив самаркандский и Ютук, возделываемых в условиях Узбекистана, проведённых с целью обоснования направления их переработки на цукаты, мармелад и пастилу. Определяли содержание сухих веществ, растворимых сухих веществ, титруемую кислотность и пектиновые вещества, рассчитывали сахарокислотный коэффициент, органолептические показатели оценивали по пятибалльной шкале дегустационной комиссией из семи человек. Содержание сухих веществ варьировало от 18,44±0,52 до 23,62±0,78 %, растворимых сухих веществ — от 16,64±1,35 до 20,54±0,84 °Вх, титруемой кислотности — от 0,47±0,04 до 0,73±0,06 %, пектиновых веществ — от 0,66±0,02 до 1,09±0,03 %. Наибольшие значения этих показателей отмечены у сорта Чернослив самаркандский, наибольший сахарокислотный коэффициент (35,8) — у сорта Блек Даймонд. Установлено, что титруемая кислотность является наиболее зависимым от года показателем (CV 8,2–10,1 %), причём максимальные значения у всех шести сортов приходились на один и тот же (2022) год, тогда как накопление пектина представляет собой устойчивый сортовой признак (CV 2,9–3,6 %) и может служить надёжным критерием при распределении сырья на желейные изделия. Общая органолептическая оценка составила 4,2–4,8 балла. Для производства цукатов рекомендованы сорта Монфор и Чернослив самаркандский, для мармелада и пастилы — Чернослив самаркандский и Киргизская превосходная.

Keywords: plum, Prunus domestica L, cultivar, dry matter, total soluble solids, titratable acidity, pectin, sugar–acid ratio, sensory evaluation, candied fruit, marmalade, pastille, complex processing.

Ключевые слова: слива, Prunus domestica L, сорт, сухие вещества, растворимые сухие вещества, титруемая кислотность, пектин, сахарокислотный коэффициент, органолептическая оценка, цукаты, мармелад, пастила, комплексная переработка.

Introduction

Plum (Prunus domestica L.) is one of the most widely cultivated stone fruit species and one of the most suitable for industrial processing. The combination of sugars, organic acids, pectic substances, polyphenolic compounds and mineral elements present in its fruits determines both the nutritional and the technological value of the raw material [1, 2].

In fruit processing, the suitability of raw material for a particular product is governed primarily by the contents of dry matter and total soluble solids, by titratable acidity and by the amount of pectic substances. High dry matter and sugar contents increase product yield during osmotic treatment (sugar infusion) and reduce the energy required for subsequent drying [3, 4], whereas pectic substances are responsible for gel formation and for the elastic texture of structured products such as marmalade and pastille [5, 6]. The ratio between sugars and acids — the sugar–acid ratio — is an integral indicator that determines the taste balance of the final product and the stability of the boiling process [7].

The literature shows that the chemical composition of plum fruits varies widely depending on cultivar, climatic conditions, maturity stage and season [7, 8, 9]. Consequently, a multi-year characterisation of local and introduced cultivars, followed by their allocation to specific product types, is of considerable practical importance for each growing region. For the conditions of Uzbekistan, the suitability of plum cultivars for complex (waste-free) processing — in particular, the possibility of obtaining candied fruit, marmalade and pastille from the same raw material — has not been sufficiently studied.

The aim of this study was to evaluate the biochemical characteristics of plum cultivars grown under the conditions of Uzbekistan over a five-year period and, on this basis, to develop scientifically substantiated recommendations for their allocation to candied fruit, marmalade and pastille production.

Materials and methods

Six plum cultivars grown in the Tashkent district of the Tashkent region (Uzbekistan) — Ispolinskaya (control), Black Diamond, Kirgizskaya Prevoskhodnaya, Monfort, Chernosliv Samarkandskiy and Yutuq — were used as the objects of the study. Samples were collected at the stage of consumer ripeness during five consecutive seasons (2021–2025), in three replicates per cultivar, each replicate consisting of 100 fruits.

Dry matter content was determined gravimetrically according to GOST 28561-90 by drying 5 g samples of homogenised pulp in pre-weighed glass weighing bottles at 105 °C to constant weight in an SNOL 58/350 laboratory drying oven (AB UMEGA Group, Lithuania; working range up to 350 °C, temperature control accuracy ±2 °C). Samples were weighed on a Pioneer PX224 analytical balance (Ohaus Corporation, USA; capacity 220 g, readability 0.0001 g, accuracy class I (special) according to OIML R76).

Total soluble solids were measured refractometrically according to GOST ISO 2173 – 2013 in juice pressed from the homogenised pulp, using a PAL-1 digital hand-held refractometer (Atago Co., Ltd., Japan; measuring range 0.0–53.0 °Bx, resolution 0.1 °Bx, accuracy ±0.2 °Bx, automatic temperature compensation 10–40 °C). Before each series of measurements the instrument was zeroed with distilled water at 20 °C.

Titratable acidity was determined according to GOST ISO 750 – 2013 by titrating an aqueous extract of the pulp with 0.1 N NaOH to pH 8.1 (phenolphthalein end point) and expressed as malic acid. Titration was performed with a 25 mL glass burette with 0.1 mL graduation, accuracy class A according to ISO 385 (maximum permissible error ±0.03 mL); the end point was controlled with an HI 2211 pH meter (Hanna Instruments, Romania; accuracy ±0.01 pH). The titre of the NaOH solution was checked against a standard-titre ampoule (fixanal). Pectic substances were determined by the calcium pectate method (Ermakov), with drying and weighing of the calcium pectate precipitate on the same oven and analytical balance described above. All measuring instruments had valid verification (calibration) certificates for the period of the study.

Sensory evaluation (appearance, taste, texture, aroma and overall score) was carried out by a panel of seven trained assessors on a five-point scale.

The sugar–acid ratio was calculated as the ratio of total soluble solids to titratable acidity. Data were processed in Microsoft Excel and Statistica; the arithmetic mean (M), standard deviation (SD) and coefficient of variation (CV, %) were calculated. Differences between cultivars were tested by analysis of variance (ANOVA) at $p < 0.05$.

Results and discussion

The five-year data showed that the studied cultivars differed significantly in their biochemical characteristics (Table 1).

Table 1.

Main chemical and technological indicators of plum fruits (2021–2025)

Cultivar	Dry matter, %	Total soluble solids, °Bx	Titratable acidity, %	Sugar–acid ratio	Pectin, %
Ispolinskaya (control)	22.08±0.48	18.88±0.86	0.59±0.06	32.1	0.76±0.02
Black Diamond	19.94±0.78	16.84±0.79	0.47±0.04	35.8	0.81±0.03
Kirgizskaya Prevoskhodnaya	18.44±0.52	16.80±0.43	0.57±0.06	29.7	0.98±0.03
Monfort	22.26±0.64	19.12±0.74	0.69±0.06	27.7	0.88±0.03
Chernosliv Samarkandskiy	23.62±0.78	20.54±0.84	0.73±0.06	28.1	1.09±0.03
Yutuq	20.60±1.98	16.64±1.35	0.52±0.05	32.2	0.66±0.02
Mean	**21.16**	**18.13**	**0.60**	**30.2**	**0.86**

Note: values are presented as M±SD based on five seasons (n = 5).

The difference between cultivars in dry matter accumulation reached 5.18 %. The highest content was recorded in Chernosliv Samarkandskiy (23.62±0.78 %), exceeding the control Ispolinskaya (22.08±0.48 %) by 1.54 %. Monfort also exceeded the control (22.26±0.64 %), while the lowest value was found in Kirgizskaya Prevoskhodnaya (18.44±0.52 %).

The same ranking was maintained for total soluble solids: Chernosliv Samarkandskiy (20.54±0.84 °Bx) and Monfort (19.12±0.74 °Bx) exceeded the control (18.88±0.86 °Bx) by 1.66 and 0.24 °Bx, respectively. The lowest accumulation was observed in Yutuq (16.64±1.35 °Bx) and Kirgizskaya Prevoskhodnaya (16.80±0.43 °Bx). These values are consistent with the ranges reported for European plum cultivars [1, 2].

Titratable acidity varied from 0.47±0.04 % (Black Diamond) to 0.73±0.06 % (Chernosliv Samarkandskiy). This parameter proved to be the most sensitive to the season: the coefficient of variation reached 8.2–10.1 % in all cultivars, and the maximum values were recorded without exception in 2022. In the same season the pectin content was also the highest in every cultivar, which indicates that the temperature and moisture regime of the growing period acts in the same direction on the accumulation of organic acids and of cell-wall polysaccharides [9].

From a technological point of view, the content of pectic substances is the most important indicator. The highest values were found in Chernosliv Samarkandskiy (1.09±0.03 %) and Kirgizskaya Prevoskhodnaya (0.98±0.03 %), exceeding the control (0.76±0.02 %) by 43.4 and 28.9 %, respectively, whereas the lowest value was recorded in Yutuq (0.66±0.02 %). It should be emphasised that the coefficient of variation for pectin remained within 2.9–3.6 % in all cultivars. This means that pectin accumulation depends only slightly on seasonal conditions and represents a stable cultivar-specific trait, which makes it a reliable criterion when allocating raw material to the marmalade and pastille lines [5].

The highest sugar–acid ratio was observed in Black Diamond (35.8), i.e. this cultivar has the sweetest taste profile, followed by Yutuq (32.2) and the control Ispolinskaya (32.1). The lowest values were recorded in Monfort (27.7) and Chernosliv Samarkandskiy (28.1); despite their high sugar content, these cultivars also have high acidity, which results in a balanced and characteristic flavour of the finished product.

In terms of stability, Yutuq differed markedly from the other cultivars: its coefficient of variation was 9.6 % for dry matter and 8.1 % for total soluble solids, compared with 2.2–4.7 % in the remaining cultivars. This indicates a high sensitivity of the cultivar to seasonal conditions and the need to adjust processing regimes between batches when it is used as industrial raw material [8, 10].

The results of the sensory evaluation are presented in Table 2.

Table 2.

Sensory characteristics of plum fruits and the recommended processing direction (five-point scale)

Cultivar	Appearance	Taste	Texture	Aroma	Overall score	Recommended direction
Ispolinskaya (control)	4.5	4.6	4.3	4.5	4.4	Control variant
Black Diamond	4.9	4.4	4.7	4.0	4.7	Candied fruit
Kirgizskaya Prevoskhodnaya	4.6	4.5	4.4	4.4	4.5	Marmalade, pastille
Monfort	4.8	4.8	4.8	4.6	4.6	Candied fruit, marmalade
Chernosliv Samarkandskiy	4.7	4.7	4.5	4.7	4.8	Candied fruit, marmalade, pastille
Yutuq	4.4	4.3	4.2	4.2	4.2	Pastille (purée)

Overall sensory scores ranged from 4.2 to 4.8 points. The highest values were obtained by Chernosliv Samarkandskiy (4.8 points) and Black Diamond (4.7 points). Black Diamond led in appearance (4.9 points) and texture (4.7 points) but received the lowest score for aroma (4.0 points),

which is associated with its weakly expressed aromatic profile. In contrast, all attributes of Chernosliv Samarkandskiy were balanced (4.5–4.7 points); combined with its high acidity and pectin content, this forms a characteristic taste and aroma complex.

The combined analysis of biochemical and sensory indicators leads to the following technological conclusions. In candied fruit production, high dry matter and sugar contents of the raw material shorten the duration of osmotic treatment and increase product yield [3, 4]; according to this criterion, Monfort (22.26 %; 19.12 °Bx) and Chernosliv Samarkandskiy (23.62 %; 20.54 °Bx) are the most suitable cultivars, while Black Diamond can be recommended as an additional option owing to its high sugar–acid ratio and sensory scores.

In marmalade and pastille production, the gelling capacity of the raw material is decisive, and a pectin content above 0.9 % is required [5, 6]. This requirement is fully met by Chernosliv Samarkandskiy (1.09 %) and Kirgizskaya Prevoskhodnaya (0.98 %). Moreover, the acidity of Chernosliv Samarkandskiy (0.73 %) is sufficient to ensure the sugar–acid balance, which makes it possible to reduce the amount of acid added to the marmalade formulation.

Yutuq, with its low pectin content (0.66 %), is not suitable for marmalade on its own; however, owing to the softness of its flesh and the ease of purée preparation, it can be used in pastille production in blends with cultivars rich in pectin [11].

Conclusions

1. Over five seasons (2021–2025), the dry matter content of the studied plum cultivars ranged from 18.44 to 23.62 %, total soluble solids from 16.64 to 20.54 °Bx, titratable acidity from 0.47 to 0.73 %, and pectic substances from 0.66 to 1.09 %.

2. Titratable acidity was the parameter most dependent on the season (CV 8.2–10.1 %), whereas pectin accumulation behaved as a stable cultivar-specific trait (CV 2.9–3.6 %), which allows it to be used as a reliable criterion for allocating raw material to particular product types.

3. The sugar–acid ratio varied between 27.7 and 35.8; the sweetest taste profile was formed in Black Diamond, and the most balanced profiles in Monfort and Chernosliv Samarkandskiy.

4. On the basis of the combined biochemical and sensory assessment, Monfort and Chernosliv Samarkandskiy are recommended for candied fruit production, and Chernosliv Samarkandskiy and Kirgizskaya Prevoskhodnaya for marmalade and pastille production.

5. The results obtained provide a scientific basis for the development of a complex (waste-free) processing technology in which candied fruit, marmalade and pastille are obtained from the same raw material.

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