UDC 664.85:634.22

ASSESSMENT OF THE TECHNOLOGICAL SUITABILITY OF PLUM (PRUNUS DOMESTICA L.) CULTIVARS FOR DIFFERENT PRIMARY-PROCESSING DIRECTIONS

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Abstract. Allocating fruit raw material to the processing line for which it is best suited is one of the most effective ways of increasing product yield and quality without additional investment. This study assessed six plum (Prunus domestica L.) cultivars — Ispolinskaya (control), Black Diamond, Kirgizskaya Prevoskhodnaya, Monfort, Chernosliv Samarkandskiy and Yutuq — grown under the conditions of Uzbekistan, for their suitability for three primary-processing directions: candied fruit, marmalade (syrup) and pastille (purée). Physical and mechanical characteristics of the fruits were determined instrumentally, suitability for each direction was scored on a five-point scale by a seven-member expert panel, and an integrated technological suitability index was calculated as the arithmetic mean of the three scores. Suitability for candied fruit was highest in Black Diamond (4.8 points) and Monfort (4.7 points) and lowest in Yutuq (3.7 points); suitability for marmalade was highest in Kirgizskaya Prevoskhodnaya (4.8 points) and lowest in Black Diamond (4.0 points); suitability for pastille was highest in Monfort (4.8 points) and Chernosliv Samarkandskiy (4.7 points). The integrated index ranged from 4.2 to 4.6 points, with the highest value in Monfort. Correlation analysis showed that the candied-fruit score was almost entirely determined by flesh firmness ($r = 0.945$ for the longitudinal section) and fruit mass ($r = 0.749$), while the pastille score was governed by dry matter content ($r = 0.861$). The marmalade score, in contrast, was not explained by pectin content alone ($r = 0.107$), indicating that syrup release and acid balance also contribute to this direction. The results allow the raw material to be allocated to product types on an objective, instrumentally verified basis.

Keywords: plum, Prunus domestica L., cultivar, technological suitability, flesh firmness, flesh share, candied fruit, marmalade, pastille, expert evaluation, suitability index, complex processing.

ОЦЕНКА ТЕХНОЛОГИЧЕСКОЙ ПРИГОДНОСТИ СОРТОВ СЛИВЫ (PRUNUS DOMESTICA L.) ДЛЯ РАЗЛИЧНЫХ НАПРАВЛЕНИЙ ПЕРВИЧНОЙ ПЕРЕРАБОТКИ

Аннотация. Направление плодового сырья на ту технологическую линию, для которой оно наиболее пригодно, является одним из наиболее эффективных способов повышения выхода и качества продукции без дополнительных капитальных вложений. В статье приведены результаты оценки шести сортов сливы (Prunus domestica L.) — Исполинская (контроль), Блек Даймонд, Киргизская превосходная, Монфор, Чернослив самаркандский и Ютук, возделываемых в условиях Узбекистана, по пригодности для трёх направлений первичной переработки: производства цукатов, мармелада (сиропа) и пастилы (пюре). Физико-механические показатели плодов определяли инструментально, пригодность по каждому направлению оценивали по пятибалльной шкале дегустационной комиссией из семи человек, интегральный индекс технологической пригодности рассчитывали как среднее арифметическое трёх оценок.

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Наибольшая пригодность для цукатов отмечена у сортов Блек Даймонд (4,8 балла) и Монфор (4,7 балла), наименьшая — у сорта Ютук (3,7 балла); для мармелада — у сорта Киргизская превосходная (4,8 балла), наименьшая у сорта Блек Даймонд (4,0 балла); для пастилы — у сортов Монфор (4,8 балла) и Чернослив самаркандский (4,7 балла). Интегральный индекс варьировал от 4,2 до 4,6 балла. Корреляционный анализ показал, что оценка пригодности для цукатов практически полностью определяется твёрдостью мякоти ($r = 0,945$) и массой плода ($r = 0,749$), а оценка для пастилы — содержанием сухих веществ ($r = 0,861$), тогда как оценка для мармелада не объясняется только содержанием пектина ($r = 0,107$). Полученные результаты позволяют распределять сырьё по видам продукции на объективной, инструментально подтверждённой основе.

Ключевые слова: слива, Prunus domestica L., сорт, технологическая пригодность, твёрдость мякоти, доля мякоти, цукаты, мармелад, пастила, экспертная оценка, индекс пригодности, комплексная переработка.

1. Introduction

In the fruit processing industry, the same raw material can be directed to products with very different technological requirements. Candied fruit requires pieces that retain their shape during blanching, osmotic treatment and repeated boiling; marmalade requires a raw material that releases a clear syrup and forms a stable gel; pastille requires a soft, easily puréed flesh with a high dry matter content. A cultivar that performs excellently in one of these directions may be entirely unsuitable for another [1, 2].

For this reason, the assessment of technological suitability has become a separate stage of raw material evaluation, distinct from both pomological description and chemical analysis. Instrumentally measured physical and mechanical characteristics — fruit mass, the share of edible flesh, the share of the stone and, above all, flesh firmness — largely predetermine the behaviour of the fruit during mechanical and thermal treatment [3, 4]. At the same time, the final decision in industrial practice is usually taken by expert panels, which integrate parameters that are difficult to measure instrumentally, such as the ease of stone removal, the behaviour of the skin during blanching and the appearance of the semi-finished product.

Combining both approaches — instrumental measurement and expert scoring — and quantifying the relationship between them makes it possible to replace subjective cultivar selection with an objective, reproducible procedure. Such an approach is particularly important for complex (waste-free) processing schemes, in which several products are obtained from the same batch of raw material [5, 6, 7].

The aim of this study was to assess the suitability of plum cultivars grown under the conditions of Uzbekistan for candied fruit, marmalade and pastille production, to calculate an integrated technological suitability index and to establish which physical and mechanical characteristics determine the expert scores for each processing direction.

2. Materials and Methods

Six plum cultivars grown in [region / province, district] — Ispolinskaya (control), Black Diamond, Kirgizskaya Prevoskhodnaya, Monfort, Chernosliv Samarkandskiy and Yutuq — were used as the objects of the study. Fruits were harvested at the stage of technical ripeness, in three replicates per cultivar, each replicate consisting of 100 fruits.

Fruit mass was determined on an electronic balance with an accuracy of 0.01 g; the mass fractions of flesh, skin, stalk and stone were established by dissecting the fruits; flesh firmness was measured with

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a penetrometer in the transverse and longitudinal sections of the fruit and expressed in kgf; the force required to detach the stalk was measured with a dynamometer.

Technological suitability for each of the three directions — candied fruit, marmalade (syrup) and pastille (purée) — was scored on a five-point scale by a panel of seven trained assessors. For candied fruit the panel evaluated the retention of fruit shape after blanching and boiling, the uniformity of the halves and the ease of stone removal; for marmalade, the yield and clarity of the released syrup and the firmness of the gel formed; for pastille, the ease of pulping, the homogeneity of the purée and the elasticity of the dried layer. The integrated technological suitability index was calculated as the arithmetic mean of the three scores.

Data were processed in Microsoft Excel; the arithmetic mean and Pearson correlation coefficients (r) between the instrumental characteristics and the expert scores were calculated. Differences between cultivars were tested by analysis of variance (ANOVA) at $p < 0.05$.

3. Results and Discussion

The physical and mechanical characteristics of the fruits of the studied cultivars are presented in Table 1.

Table 1

Physical and mechanical characteristics of the fruits of the studied plum cultivars

Cultivar	**Fruit mass, g**	**Flesh share, %**	**Stone share, %**	**Firmness, transverse section, kgf**	**Firmness, longitudinal section, kgf**	**Stalk detachment force, kgf**
Ispolinskaya (control)	45.00	85.3	3.8	2.39	2.88	0.58
Black Diamond	63.18	87.3	2.1	3.72	3.91	0.82
Kirgizskaya Prevoskhodnaya	43.23	85.5	3.7	2.13	2.53	0.53
Monfort	56.94	84.2	3.3	2.54	3.18	0.76
Chernosliv Samarkandskiy	41.57	84.5	3.6	2.72	3.33	0.95
Yutuq	42.73	87.2	2.6	1.97	2.17	0.61
Mean	**48.78**	**85.7**	**3.1**	**2.58**	**3.00**	**0.71**

Fruit mass varied from 41.57 g (Chernosliv Samarkandskiy) to 63.18 g (Black Diamond), the share of edible flesh from 84.2% (Monfort) to 87.3% (Black Diamond), and flesh firmness from 1.97 to 3.72 kgf in the transverse section and from 2.17 to 3.91 kgf in the longitudinal section. The widest range was recorded for firmness, which differed between the extreme cultivars by a factor of 1.9 — a far greater spread than that of any other characteristic measured. On the basis of these data the cultivars were evaluated for their suitability for each processing direction (Table 2).

Table 2

Technological suitability of plum cultivars for primary-processing directions (five-point scale)

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Cultivar	Suitability for candied fruit, points	Suitability for marmalade (syrup), points	Suitability for pastille (purée), points	Integrated suitability index	Recommended main direction
Ispolinskaya (control)	4.3	4.6	4.5	4.5	Candied fruit, marmalade, pastille
Black Diamond	4.8	4.0	4.1	4.3	Candied fruit
Kirgizskaya Prevoskhodnaya	3.9	4.8	4.2	4.3	Marmalade, pastille
Monfort	4.7	4.2	4.8	4.6	Candied fruit, pastille
Chernosliv Samarkandskiy	4.5	4.4	4.7	4.5	Candied fruit, marmalade, pastille
Yutuq	3.7	4.5	4.4	4.2	Marmalade, pastille
Mean	**4.3**	**4.4**	**4.5**	**4.4**	—

Suitability for candied fruit. The highest scores were obtained by Black Diamond (4.8 points) and Monfort (4.7 points), exceeding the control Ispolinskaya (4.3 points) by 0.5 and 0.4 points, respectively. Both cultivars combine a large fruit size with dense flesh, which enables the halves to retain their shape during blanching and repeated boiling in syrup. Kirgizskaya Prevoskhodnaya scored 3.9 points and Chernosliv Samarkandskiy 4.5 points, while the lowest score was recorded in Yutuq (3.7 points), 0.6 points below the control. The low result of Yutuq is explained by the softer consistency of its flesh, as a consequence of which the fruit loses its shape during candying.

Correlation analysis confirmed this interpretation quantitatively. The candied-fruit score was almost functionally related to flesh firmness in the longitudinal section ($r = 0.945$) and strongly related to firmness in the transverse section ($r = 0.825$) and to fruit mass ($r = 0.749$), whereas its relationship with dry matter content was weak ($r = 0.424$). Firmness measured with a penetrometer can therefore be used as a rapid, non-expert screening criterion for selecting raw material for the candied fruit line, which is of practical value when incoming batches have to be sorted quickly [3, 4].

Suitability for marmalade. The highest score was obtained by Kirgizskaya Prevoskhodnaya (4.8 points), followed by the control Ispolinskaya (4.6 points), Yutuq (4.5 points) and Chernosliv Samarkandskiy (4.4 points); the lowest score was recorded in Black Diamond (4.0 points). Kirgizskaya Prevoskhodnaya combines a high content of pectic substances with a moderate dry matter content, which ensures both an abundant release of syrup and the formation of a firm gel structure [5, 7].

It should be noted, however, that the marmalade score was not explained by pectin content alone: the correlation between them was weak ($r = 0.107$). Chernosliv Samarkandskiy, which has the highest pectin content of all the cultivars studied, received only an average score for this direction, because its very high dry matter content reduces the yield of free syrup. The suitability of a cultivar for marmalade is therefore determined not by the absolute pectin content but by the combination of pectin, syrup yield and acid balance, and cannot be predicted from a single analytical parameter.

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Suitability for pastille. The highest scores were obtained by Monfort (4.8 points) and Chernosliv Samarkandskiy (4.7 points), against 4.5 points in the control; the lowest score was recorded in Black Diamond (4.1 points). This direction showed a strong positive correlation with dry matter content (r = 0.861) and a pronounced negative correlation with the share of flesh (r = −0.792). The latter relationship is not paradoxical: cultivars with the highest flesh share (Black Diamond, 87.3%; Yutuq, 87.2%) are also those with the lowest dry matter content, so that a larger volume of purée has to be evaporated to reach the required consistency of the dried layer, which lengthens the drying stage and impairs the elasticity of the product [6].

Integrated suitability index. The index ranged from 4.2 to 4.6 points. The highest value was recorded in Monfort (4.6 points), followed by Ispolinskaya (control) and Chernosliv Samarkandskiy, both with 4.5 points; these cultivars are distinguished by a high universal technological potential, i.e. they can be processed into any of the three products without a substantial loss of quality. By contrast, Black Diamond and Kirgizskaya Prevoskhodnaya obtained the same index (4.3 points) through completely different score profiles: 4.8 points for candied fruit and 4.0 for marmalade in the first case, and 3.9 for candied fruit and 4.8 for marmalade in the second. This demonstrates that the integrated index should be used together with, and not instead of, the individual scores: it characterises the versatility of a cultivar, whereas the individual scores identify its specialisation.

The mean scores calculated for the whole set of cultivars were 4.3 points for candied fruit, 4.4 points for marmalade and 4.5 points for pastille, giving an overall mean technological suitability index of 4.4 points. The relatively low mean for the candied-fruit direction reflects its stricter requirements regarding the mechanical properties of the raw material, while the pastille direction, which uses puréed fruit, imposes the fewest restrictions and can additionally accept non-standard and mechanically damaged fruits — an important advantage within a complex processing scheme.

4. Conclusions

1. The suitability of the studied plum cultivars for candied fruit production ranged from 3.7 to 4.8 points, for marmalade from 4.0 to 4.8 points and for pastille from 4.1 to 4.8 points, while the integrated technological suitability index varied between 4.2 and 4.6 points.

2. The expert score for the candied-fruit direction is almost entirely determined by the mechanical properties of the raw material: its correlation with flesh firmness in the longitudinal section reached r = 0.945, which allows penetrometry to be used as a rapid screening criterion when sorting incoming batches.

3. The score for the pastille direction is governed by dry matter content (r = 0.861) and is negatively related to the share of flesh (r = −0.792), whereas the score for the marmalade direction is not explained by pectin content alone (r = 0.107) and requires the combined evaluation of pectin, syrup yield and acid balance.

4. Monfort (index 4.6 points), Ispolinskaya and Chernosliv Samarkandskiy (4.5 points each) possess the highest universal technological potential, whereas Black Diamond and Kirgizskaya Prevoskhodnaya are clearly specialised cultivars, recommended respectively for candied fruit and for marmalade and pastille production.

5. The combined use of instrumental measurement and expert scoring makes it possible to allocate plum raw material to product types on an objective basis and provides a foundation for a complex (waste-free) processing scheme in which candied fruit, marmalade and pastille are obtained from the same batch of raw material.

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