

Fruit quality changes during marketing of new plum cultivars (*Prunus domestica* L.)

E. VANGDAL, S. FLATLAND, R. NORDBØ

Bioforsk Vest Ullensvang, Lofthus, Norway

ABSTRACT: Registrations of crop, fruit size and fruit flavour in the plum cultivar testing programmes in Norway indicated that Souffriau, Avalon, Reeves, Excalibur and Jubileum could be valuable cultivars in commercial plum production in Norway. Norwegian plums are aimed at the fresh fruit market; hence, shelf life of new cultivars is very important. In short-term storage experiments the cultivars were compared to the standard cultivar Victoria. No significant changes in the content of soluble solids during storage were found in the cultivars tested; however, titratable acidity decreased, and as a consequence, the soluble solids:titratable acidity ratio increased. Nevertheless, these changes did not make the fruit unacceptable to consumers. The most important quality factor limiting shelf life of the plum cultivars tested was softening. Based on postharvest changes in several quality factors and susceptibility to fungal decay, Reeves had longest shelf life, Avalon, Jubileum and Victoria medium, while Excalibur and Souffriau had rather short shelf life.

Keywords: postharvest; soluble solids content; titratable acidity; firmness; fungal decay

Norwegian plum production is aimed at the fresh fruit market. Though plums can be stored commercially in CA-storage (STREIF 1989) and ultra low oxygen (ULO) storage (GOLIAS 2007), this is not common practice in Norway. However, during short time storage and transportation the plums are kept at low temperatures (2–4°C).

Major commercial plum cultivars grown in Norway include Edda, Opal, Mallard and Victoria (VANGDAL 2000). The early ripening cultivar Opal is dominant, and there is space in the market for large fruited late ripening cultivars. Victoria is popular among the consumers; however, these plums are highly susceptible to gumosis, a physiological disorder of the fruit flesh. No solution to this problem has been found, and the growers are looking for new cultivars to replace Victoria in Norwegian plum orchards.

The market wants plums of a reasonably good quality for at least three weeks after harvest. It is a well-known problem that the temperature and humidity is suboptimal during marketing with changing temperatures and rather dry air in the shops. The losses during marketing of plums in Norway has been estimated to be close to 20% (VANGDAL 2003). In addition, the consumers wish the plums to keep fresh for several days after the purchase.

The major factors limiting the shelf life of plums are softening (overripe), fungal decay, reduced fla-

vour quality (too low acidity, no aroma) and less favourable appearance (lack of freshness, shriveling or bruising). New cultivars should have fruits that stay firm during marketing, are resistant to fungal diseases and have a fresh appearance; they should also have good flavour even after several weeks in the marketing chain.

This paper presents results from a short-term storage of new plum cultivars simulating the time needed from harvest to consumption. The results show how these cultivars perform in the marketing chain, and which cultivars need special attention to avoid large losses during marketing.

MATERIALS AND METHODS

Cultivars

The following cultivars were tested:

- Reine Claude Souffriau (BELMANS 1986) ripens approximately 7 days after Opal. Rounded, dark blue, medium sized fruits with a good appearance. The fruit quality is good.
- Avalon (JONES 1989) is a medium to late ripening cultivar; approximately 7 days earlier than Victoria. The plums have excellent taste, however, the fruit skin is thin, and bruising may be a problem during marketing.

- Excalibur (JONES 1989) is an introduction from the same breeding programme as Avalon. It ripens approximately two days before Victoria. The taste quality is excellent; the plums have medium content of soluble solids and low content of titratable acidity, and a very good aroma.
- Reeves (ANDERSON, OKIE 1997) is a Canadian cultivar ripening at the same time as Victoria. The plums are firm, low in sugar and acidity; they have a pleasant, though not very strong, taste and a very attractive appearance.
- Jubileum (WERLEMARK 1995) is a Swedish cultivar ripening one week later than Victoria. The plums are large, oval and dark blue; they are susceptible to preharvest fungal diseases.

Orchard management and harvesting

The plums were grown in the experimental orchard at Bioforsk Vest Ullensvang in the fjord districts of Western Norway. The trees were five to eight year old grafted on St. Julien A rootstock. Planting distance was 2 × 4.5 m and trees were pruned with a vertical axis. A 1-m wide stripe along the tree rows was kept free of weeds by herbicides. The orchard management (fertilizing, plant protection etc.) was made according to standard programmes in the area. Fruit thinning was done by hand when necessary in June (6 weeks after petal fall) to approximately 20 fruitlets per 1 m of branch.

The fruits were picked when at least half of the fruit had reached optimum harvest date. All fruits were picked and divided into three samples according to the degree of maturity: slightly ripe, tree ripe (optimum harvest date) and well ripe.

Fruit quality analyses and storage

18 subsamples (each of 10 fruits) from each degree of ripening were brought to the laboratory for analyses

or storage. 3 samples of each degree of ripening were analyzed at the day of harvest, 6 samples were stored at 20°C with RH 75% ± 5%, while 9 samples were stored at 4°C with 92% ± 5% RH. After 1, 2 and 3 weeks 3 samples from each degree of ripening and temperature were removed from storage for quality analyses (after three weeks only the samples from 4°C were used).

Ground colour was assessed according to a scale from 1 (= green) to 9 (= yellow) and cover colour according to a scale from 0 (= no cover colour) to 100 (= total red/blue cover colour). Firmness was measured by the Durofel Instrument (Copa Technologie S.S./CTIFL, France) with a 0.25 cm² plunger (PLANTON 1992). Soluble solids content was measured by the refractometer, and titratable acidity by titration of diluted juice samples with NaOH-solution to pH = 8.1. When samples were removed from the storage, the number of fruits decayed due to fungal diseases was registered.

Statistical analyses

Statistical analyses were carried out using the software Minitab[®] and the statistical package of Excel[®].

RESULTS AND DISCUSSION

Fruit quality

Soluble solids content ranged from 11.9% in Reeves to 15.8% in Avalon (Table 1). In a study of consumers' acceptance, VANGDAL (1980) found that plums with less than 12.5% soluble solids were not acceptable for most of the consumers. The soluble solids content of Reeves was below this limit. However, as Reeves had low titratable acidity, the soluble solids:titratable acidity ratio was higher in this cultivar than of most other cultivars tested. Avalon had the highest content of titratable acidity and the lowest ratio. Avalon plums are known as very tasty. However,

Table 1. Content of soluble solids and titratable acidity, soluble solids:titratable acidity ratio and firmness in six plum cultivars. Average of three years, three maturity stages and three replicates

Cultivar	Soluble solids content (%)	Titratable acidity (%)	Soluble solids:titratable acidity	Firmness (Durofel units)
Souffriau	13.0 ab*	1.14 c	11.4	63 c
Avalon	15.8 e	2.30 e	6.9	65 bc
Excalibur	13.5 c	0.95 b	14.2	54 a
Reeves	11.9 a	0.90 a	13.2	60 b
Jubileum	13.4 bc	1.15 c	11.7	53 a
Victoria	15.1 d	1.43 d	10.6	53 a
<i>P</i> -value	0.0011	< 0.0001	–	0.0002

*Means followed by the same letter within a column are not significantly different ($P > 0.05$)

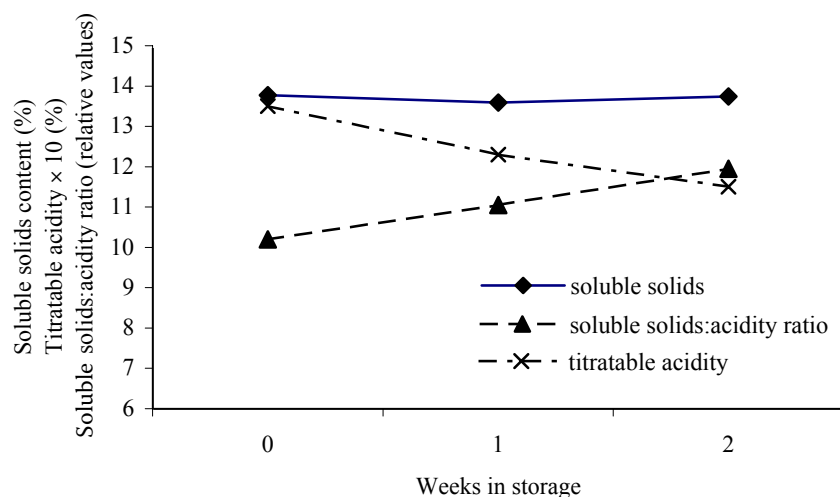


Fig. 1. Content of soluble solids and titratable acidity and the soluble solids:titratable acidity ratio in plums during storage at 4°C. Average of six cultivars, three stages of ripening, three years and three replicates

Table 2. Discarded fruit (%) due to fungal attacks after 2 weeks in storage at 4°C. Average of three years and three replicates

Cultivar	Stage of ripening at harvest			Average
	slightly ripe	tree ripe	well ripe	
Avalon	1	6	13 a*	7
Reeves	2	6	17 a	8
Victoria	1	20	43 bc	21
Jubileum	11	28	37 ab	25
Souffriau	5	12	65 bc	27
Excalibur	8	28	68 c	34
<i>P</i> -value	(0.06)	(0.06)	0.001	(0.12)

*Means followed by the same letter within a column are not significantly different ($P > 0.05$)

when slightly ripe, the consumers found such plums too acid (data not shown).

The content of soluble solids did not change significantly during storage (Fig. 1). VANGDAL (1981) found that the soluble solids content increased in Mallard plums during storage. Significant changes in soluble solids content were not observed in any of the cultivars tested. The decrease in titratable acidity was in the range of 15–20% from slightly ripe to well ripe plums. A similar decrease was observed after 2 weeks of storage (Fig. 1). The decrease (in %)

in plums high in titratable acidity (Avalon) was not significantly different from the decrease in Excalibur and Reeves plums. The soluble solids:titratable acidity ratio increased on average from 10.2 to 11.9 after 2 weeks of storage. The changes in soluble solids and titratable acidity did not change to such an extent to limit the shelf life of the cultivars tested.

The fruits of Excalibur were more aromatic than the fruits of the other cultivars. The volatile aroma components evaporated and disappeared during storage. This may limit the shelf life of this cultivar.

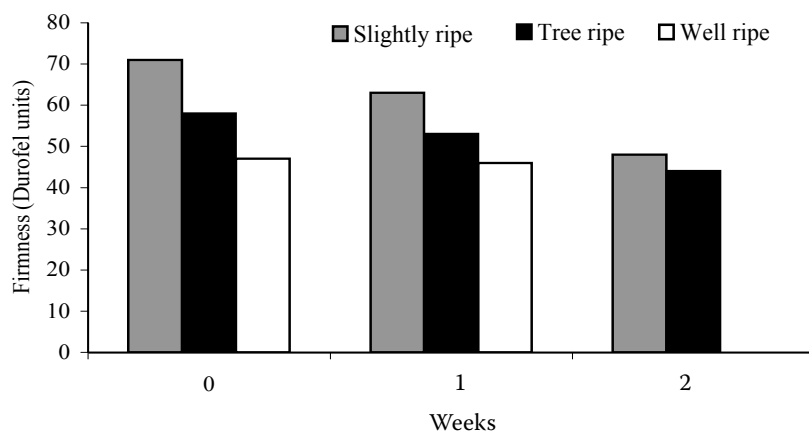


Fig. 2. Firmness of Souffriau plums harvested at three different stages of ripening and stored at 4°C for two weeks. Average of three years and three replicates

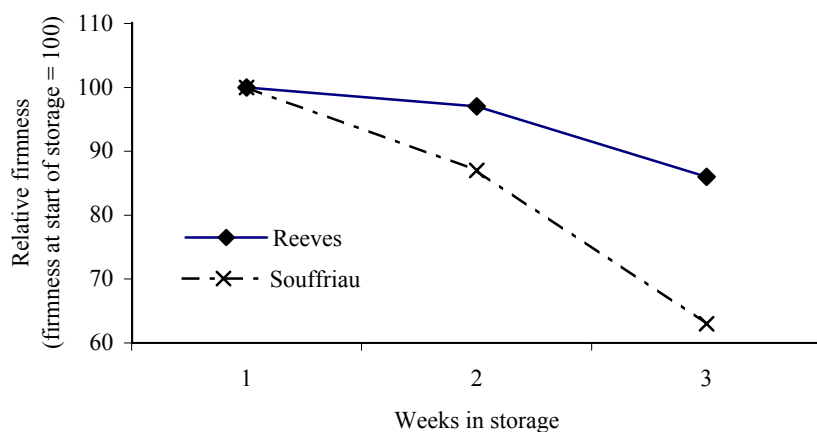


Fig. 3. Relative firmness of Reeves and Souffriau plums during 2-week storage at 4°C. Average of three stages of ripening, three years and three replicates

During storage an increase in red or blue cover colour and a shift from green to yellow ground colour was observed. The colour changes did not influence the length of the shelf life. No shriveling or lack of freshness was observed.

Firmness

The plums softened during postharvest storage. The slightly ripe plums softened more rapidly than the plums harvested at a more mature stage, as shown for Souffriau plums in Fig. 2. Using the Durofel firmness tester, firmness below 50 Durofel units was regarded as too soft by consumers (data not shown). The Souffriau plums harvested slightly ripe were too soft after 2 weeks of storage.

Some cultivars lost firmness more slowly than others. In Reeves plums the firmness was reduced by 15% after two weeks storage and in Jubileum by 24%. In the other cultivars tested, the reduction in firmness ranged from 32% to 37%. The relative decrease in firmness during storage in Souffriau and Reeves plums is shown in Fig. 3.

Fungal decay

It is difficult to compare the cultivars' susceptibility to fungal decay, as the cultivars are picked at

different dates under different climatic conditions. Plums picked when wet, are more susceptible to fungal decay than plums harvested dry (VANGDAL, BØRVE 2002).

Avalon and Reeves had fewer incidences of fungal diseases than the other cultivars tested. In plums picked well ripe the differences between the cultivars were statistically significant (Table 2). In plums picked slightly ripe or tree ripe similar tendencies were seen. Large annual variations between replicates were observed, however, the differences were not significant ($P > 0.05$). No significant differences were found between the years, either. BØRVE and VANGDAL (2007) also reported that Excalibur is highly susceptible to postharvest fungal pathogens; in this respect, Jubileum was stronger than Victoria and Reeves.

The well ripe plums were more susceptible to fungal decay than tree ripe and slightly ripe fruits (Table 2). The amount of discarded fruits after 2 weeks of storage reached 4% for slightly ripe, 16% for tree ripe, and 48% for well ripe plums. These differences were statistically significant ($P < 0.001$).

Shelf life

Based on the results presented above, and the general impression of the growers testing the cultivars,

Table 3. Factors important to shelf life in six plum cultivars and overall impression of shelf life. Three-year experiments with three stages of maturity and storage at 4 and 20°C

Cultivar	Ability to stay firm	Susceptibility to fungal diseases	Overall impression of shelf life
Souffriau	becomes soft	susceptible	short
Avalon	medium	strong	medium
Excalibur	becomes soft	susceptible	short
Reeves	keep firm	strong	long
Victoria	medium	medium	medium
Jubileum	medium	susceptible	medium

they were divided into different classes with short, medium or long shelf life. As shown in Table 3 the shelf life of Reeves was classified as long, Jubileum, Avalon and Victoria were marked as medium, while the shelf life of Souffriau and Excalibur was classified as short.

CONCLUSION

The shelf life of plums is limited due to softening, fungal decay or changes in fruit quality factors. In the six cultivars tested, including the standard cultivar Victoria, the softening and susceptibility to fungal diseases were the most important factors.

The cultivar Reeves had longer shelf life than the standard cultivar Victoria, while Souffriau and Excalibur had shorter shelf life. The shelf life of Avalon and Jubileum was similar to that of Victoria.

References

- ANDERSON R.L., OKIE D., 1997. Plums. In: Brooks and Olmo Register of Fruit and Nut Varieties. 3rd edition. ASHS Press: 584–627.
- BELMANS K., 1986. Op zoek naar nieuwe rassen: Castor (zoete kers) en Reine Claude Souffriau (pruim). Boer en de Tuinder, 92: 19.
- BØRVE J., VANGDAL E., 2007. Fungal pathogens causing fruit decay on plum (*Prunus domestica* L.) in Norway. Acta Horticulturae, 734: 367–369.

- GOLIAS J., 2007. Postharvest response of plum fruits (*Prunus domestica* L.) to low oxygen atmosphere storage. Acta Horticulturae, 734: 431–440.
- JONES R., 1989. Plum Breeding. AFRC Institute of Horticultural Research. Annual Report, 1988: 32.
- PLANTON G., 1992. Fermenté des fruits et légumes. Des nouveaux outils de mesure. Infos-CTIFL, 82: 27–28.
- STREIF J., 1989. Storage behaviour of plums. Acta Horticulturae, 258: 177–183.
- VANGDAL E., 1980. Threshold values of soluble solids in fruit determined for the fresh fruit market. Acta Agriculturae Scandinavica, 30: 445–448.
- VANGDAL E., 1981. Postharvest ripening of plums. Forsking og Forsøk i Landbruket, 32: 13–20. (in Norwegian)
- VANGDAL E., 2000. The Plum Book. Plateforsk Grønn Forsking, 13: 18. (in Norwegian)
- VANGDAL E., BØRVE J., 2002. Pre- and postharvesting Ca-treatment of plums (*Prunus domestica* L.). Acta Horticulturae, 577: 125–128.
- VANGDAL E., 2003. Losses during marketing of plums. Bondevennen, 34/35: 12–14. (in Norwegian)
- WERLEMARK G., 1995. Jubileum. In: Sortar förädlade vid Balsgård 1943–1994. Institutionen för hortikulturell växtförädling – SLU: 43.

Received for publication February 21, 2007

Accepted after corrections March 20, 2007

Změny v kvalitě plodů v posklizňovém období u nových odrůd slivoní (*Prunus domestica* L.)

ABSTRAKT: Hodnocení výnosů, velikosti plodů a chuti plodů v rámci programu odrůdových zkoušek v Norsku ukázalo, že Souffriau, Avalon, Reeves, Excalibur a Jubileum by mohly být cennými kultivary pro tržní pěstování v Norsku. Slivoně v této zemi jsou určeny pro konzum v čerstvém stavu, a proto je u nich důležitá dobrá pultová skladovatelnost. V krátkodobých skladovacích pokusech byly tyto kultivary srovnávány se standardní odrůdou Victoria. V průběhu skladování nebyly u plodů těchto kultivarů zjištěny žádné významné rozdíly v obsahu refraktometrické sušiny, nicméně jejich titrační kyselost se snižovala a v důsledku toho se zvyšoval poměr mezi refraktometrickou sušinou a titrační kyselostí. Tyto změny však nebyly takového charakteru, aby byly pro spotřebitele nepřijatelné. Nejdůležitějším faktorem kvality plodů omezujícím délku pultové skladovatelnosti zkoušených plodů bylo měknutí dužniny. Na základě posklizňových změn u několika faktorů kvality plodů a k citlivosti k hnilobám houbového původu se kultivar Reeves vyznačoval nejdelší pultovou skladovatelností, Avalon, Jubileum a Victoria měly tuto skladovatelnost středně dlouhou, zatímco Excalibur a Souffriau měly tuto skladovatelnost pouze krátkou.

Klíčová slova: posklizňové hodnocení; refraktometrická sušina; titrační kyselost; pevnost dužniny; houbové hniloby

Corresponding author:

Dr. EIVIND VANGDAL, Bioforsk Vest Ullensvang, 5781 Lofthus, Norway
tel.: + 479 062 8035, fax: + 475 366 6996, e-mail: eivind.vangdal@bioforsk.no
