

Keeping quality of strawberry cultivars during ice bank cooling

Holdbarhed af jordbærsorter ved vådkøling

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Summary

Two experiments were carried out to find strawberry cultivars with a good keeping quality. Evaluation of the influence of berry size and maturity was included in the experiments. The cvs 'Dania', 'Elsanta', 'Senga Sengana', and 'Zefyr' were stored in an ice bank cooler for 7 days. The temperature was 2.5 °C and the relative humidity of the air 99-100%.

The cv. 'Elsanta' had a higher berry weight

than the other three cultivars, but the better keeping quality in this cultivar could not be related to the berry size. Berries with green tips did not keep better than more ripe ones.

The highest anthocyanin content was found in the cv. 'Senga Sengana', but in the cv. 'Elsanta' this was increasing during storage. The highest vitamin C content was found in the cultivars 'Elsanta' and 'Zefyr'.

Key words: *Fragaria ananassa*, strawberries, storage, cultivars, ice bank cooling, keeping quality, berry weight, weight loss, composition, surface colour.

Resumé

For at finde jordbærsorter med god holdbarhed blev der udført to forsøg. Betydningen af bærestørrelse og modenhed blev vurderet. Sorterne 'Dania', 'Elsanta', 'Senga Sengana' og 'Zefyr' blev opbevaret i vådkøler i 7 dage. Temperatur: 2,5 °C, luftfugtighed: 99-100 pct.

Sorten 'Elsanta' havde en større bærvægt end de andre tre sorter, men den bedre holdbarhed i

denne sort kunne ikke relateres til bærestørrelsen. Bær med grøn spids holdt sig ikke bedre

end mere modne bær.

Det største anthocyaninindhold blev fundet i sorten 'Senga Sengana', men i sorten 'Elsanta' forøgedes dette indhold under køleopbevaring. Det største vitamin C indhold blev fundet i sor-

Nøgleord: *Fragaria ananassa*, jordbær, opbevaring, sorter, vådkøling, holdbarhed, bærvægt, vægttab, kemisk sammensætning, overfladefarve.

Introduction

The soft fruits from the strawberry plant are easily spoiled after harvest if kept at room temperature (9,13). This quality decrease is mainly caused by fungi (5). So, the fungal growth must be inhibited early after harvest and as effectively as possible by ensuring a high standard of hygiene at harvest time and during storage. Different preservation techniques have been tried to prolong shelf life of the berries including irradiation, hypobaric pressure and CA-storage (4,6,7,8,9,10,11). From an economic view and from the consumers opinions, however, normal cold storage and ice bank cooling are the most acceptable storage methods. Due to the very high humidity in the air the ice bank cooling might be potentially better than normal cold storage, but such facilities are not yet used widespread.

Many different cultivars are available. The cv. 'Elsanta' was chosen for the experiments because it is a new cultivar in Denmark which had a good keeping quality after 24 hours at 20 °C in recent cultivar trials (2); the other three cultivars were chosen because they have been dominating cultivars in Denmark for many years.

The aim of experiment no. I was to find the best suitable cultivar for storage and to determine how the maturity level influences the keeping quality. The aim of experiment no. II was to determine how the berry weight of the cv. 'Elsanta' influences the keeping quality.

Material and methods

Sampling and storage

Plants of strawberry (*Fragaria ananassa* Duchesne) were grown in the experimental fields of The Research Centre for Horticulture in Årslev.

Experiment no. I

Three cultivars, 'Elsanta', 'Senga Sengana' and 'Zefyr', were harvested 21 June, 1989 and the cv. 'Dania' was harvested 5 July. Fruits at two maturity stages, green tip and red, respectively, were harvested the same day by hand.

Experiment no. II

Solely red berries from the cv. 'Elsanta', harvested 20 Juni, 1990, were divided into three weight classes.

After harvest and handling in the morning the berries were transferred to the ice bank cooling system, kept at 2.5°C and a relative humidity of 99-100 %.

In both experiments samples were analyzed after 0, 2, 5 or 7 days, respectively. Two replications were used for each treatment with 25 berries kept in cardboard boxes.

Measurements and Analysis

Weight loss (water loss), was determined by weighing berries before and after the storage periods. Vitamin C (ascorbic acid + dehydroascorbic acid) was found by potentiometric titration with dichlorophenol-indophenol after reduction of dehydroascorbic acid to ascorbic acid by homocystein by use of a method modified after Pongracz (10) and Rosenfeldt (12).

Anthocyanin was measured spectrophotometrically using a pH-differential method (15) and calculated as mg cyanidin-3-glucoside in 100 g fresh fruit. Titratable acid was determined by titration of samples to pH 8.1 with 0.1 N NaOH and calculated as g citric acid in one kg fresh fruit.

Soluble solids were determined by refractometry, surface colour by use of a Hunterlab colorimeter (1). L means "lightness" (100=white, 0=black), a means "redness" (highest value = most

Table 1. Cultivar differences. Average of maturity and harvest date. Exp. I. SS=Soluble solids. Acid=Citric acid. Sortsforskelle. Gennemsnit af modenhed og høstdato. Forsøg I. RT=Opløseligt tørstof. Syre=Citronsyre.

Cultivar	Initial berry weight (g)	Weight loss (%) 5 days	Anthocyanin mg/100 g	Surface colour			SS (%)	Acid g/kg	pH	Vitamin C mg/100 g
				L	a	b				
Sort	Initial bærvægt (g)	Vægttab pct. 5 døgn	Anthocyanin mg/100 g	Overfladefarve			RT pct.	Syre g/kg	pH	Vitamin C mg/100 g
				L	a	b				
'Dania'	11	3.3	24	39	35	26	8.1	11.3	3.1	53
'Elsanta'	16	2.3	15	39	33	27	7.2	9.5	3.4	100
'Sengana'	10	2.9	41	30	26	15	7.3	10.3	3.3	58
'Zefyr'	11	2.6	24	38	32	25	6.9	10.4	3.2	92
LSD	1	0.2	2	1	1	1	0.3	1.1	0.1	9

Table 2. Effects of maturity. Average of cultivars and storage time. Exp. I. SS=Soluble solids.

Acid=Citric acid.

Virkning af modenhed. Gennemsnit af sorter og lagertid. Forsøg I. RT=Opløseligt tørstof. Syre=Citronsyre.

Maturity level	Initial berry weight (g)	Weight loss (%) 5 days	Antho- cyanin mg/100 g	Surface colour			SS (%)	Acid g/kg	pH	Vitamin C mg/100 g
				L	a	b				
Moden- hedstrin	Initiel bærvægt (g)	Vægt- tab pct. 5 døgn	Antho- cyanin mg/100 g	Overfladefarve			RT pct.	Syre g/kg	pH	Vitamin C mg/100 g
				L	a	b				
Green tip <i>Grøn spids</i>	11	2.9	19	40	30	26	7.2	11.2	3.2	76
Red berry <i>Røde bær</i>	13	2.7	34	33	33	20	7.5	9.6	3.3	76
LSD	1	0.1	8	1	1	1	n.s.	0.4	0.1	n.s.

red surface), b means "Yellowness" (highest value=most yellow surface).

Visual and sensory evaluation of acceptability was carried out by two panellists.

LSD in the tables is calculated on a 5% basis.

Results

Cultivar differences

The cv. 'Elsanta' had the highest mean berry weight and the cv. 'Senga Sengana' the lowest one (Table 1). The weight loss after five days was greatest in the cv. 'Dania' and least in the cv. 'Elsanta'. The anthocyanin content was much higher in the cv. 'Senga Sengana' than in the other cultivars and lowest in the cv. 'Elsanta'. The surface colour of the cv. 'Senga Sengana' was darker and less red and yellow than the other cultivars. The soluble solids was highest in the cv. 'Dania'. The highest vitamin C content was found in the cvs 'Elsanta' and 'Zefyr'.

Maturity

The red and riper berries had the highest berry

weight, a higher anthocyanin content, and the surface colour was darker and redder and less yellow than the ones with green tips. The acid content was lowest in the red ones.

Storage time

A weight loss increase and a decrease in vitamin C was found (Table 3). Other parameters did not change significantly during the storage period.

Sensory evaluations showed that all samples were acceptable after five days (Table 4), but the cvs 'Dania', 'Senga Sengana' and 'Zefyr' had wrinkled surfaces. After seven days the cv. 'Elsanta' had still a smooth surface and the long storage period was not detectable. Only the cv. 'Zefyr' (with green tips) was unacceptable.

Keeping quality and berry size

In cv. 'Elsanta' in exp. II (Table 6) the weight loss and the anthocyanin content increased during the storage. The surface colour changed, and the berries became brighter, redder and yellower. The sensory evaluation: In all cases the qual-

Table 3. Effects from storage time. Average of cultivar and maturity. Exp. I. SS=Soluble solids. Acid=Citric acid.*Virkninger af lagertid. Gennemsnit af sort og modenhed. Forsøg I. RT=Opløseligt tørstof. Syre=Citronsyre.*

Storage days	Initial berry weight (g)	Weight loss (%)	Antho- cyanin mg/100 g	Surface colour			SS (%)	Acid g/kg	pH	Vitamin C mg/100 g
				L	a	b				
Dage på køl	Initiel bærvægt (g)	Vægt- tab pct.	Antho- cyanin mg/100 g	Overfladefarve			RT pct.	Syre g/kg	pH	Vitamin C mg/100 g
				L	a	b				
0	-	0.0	20	36	31	24	7.1	10.6	3.3	91
2	12	2.3	27	36	30	23	7.4	10.4	3.2	67
5	12	2.8	30	35	31	23	7.3	10.4	3.2	70
7	12	3.3	28	38	32	24	7.6	10.0	3.2	75
LSD	n.s.	0.4	n.s.	1	1	1	n.s.	n.s.	n.s.	16

Table 4. Sensory evaluation. Exp. I.
Sensorisk bedømmelse. Forsøg I.

Age <i>Alder</i>	Cultivar <i>Sort</i>	Maturity <i>Modenhedstrin</i>	Appearance <i>Udseende</i>	Taste <i>Smag</i>
2	'Dania'	Red <i>Rød</i>	Acceptable <i>Acceptabel</i>	Acceptable <i>Acceptabel</i>
	'Elsanta'	Red <i>Rød</i>	Excellent and smooth <i>Eksellent og glat</i>	Fresh <i>Frisk</i>
	'Senga Sengana'	Red <i>Rød</i>	Dark and wrinkled <i>Mørk og rynket</i>	Very ripe <i>Meget moden</i>
	'Zefyr'	Red <i>Rød</i>	Wrinkled <i>Rynket</i>	Fresh <i>Frisk</i>
5	'Dania'	Green tip <i>Grøn spids</i>	Acceptable <i>Acceptabel</i>	Fresh <i>Frisk</i>
	'Dania'	Red <i>Rød</i>	Acceptable <i>Acceptabel</i>	Ripe <i>Moden</i>
	'Elsanta'	Green tip <i>Grøn spids</i>	Excellent and smooth <i>Eksellent og glat</i>	Fresh <i>Frisk</i>
	'Elsanta'	Red <i>Rød</i>	Excellent and smooth <i>Eksellent og glat</i>	Fresh <i>Frisk</i>
	'Senga Sengana'	Green tip <i>Grøn spids</i>	Dark and wrinkled <i>Mørk og rynket</i>	Sour <i>Sur</i>
	'Senga Sengana'	Red <i>Rød</i>	Dark and wrinkled <i>Mørk og rynket</i>	Acceptable <i>Acceptabel</i>
	'Zefyr'	Green tip <i>Grøn spids</i>	Wrinkled <i>Rynket</i>	Acceptable <i>Acceptabel</i>
	'Zefyr'	Red <i>Rød</i>	Wrinkled <i>Rynket</i>	Very ripe <i>Meget moden</i>
7	'Dania'	Green tip <i>Grøn spids</i>	Acceptable <i>Acceptabel</i>	Acceptable <i>Acceptabel</i>
	'Dania'	Red <i>Rød</i>	Acceptable <i>Acceptabel</i>	Acceptable <i>Acceptabel</i>
	'Elsanta'	Green tip <i>Grøn spids</i>	Smooth <i>Glat</i>	Fresh <i>Frisk</i>
	'Elsanta'	Red <i>Rød</i>	Smooth <i>Glat</i>	Fresh <i>Frisk</i>
	'Senga Sengana'	Green tip <i>Grøn spids</i>	Dark and wrinkled <i>Mørk og rynket</i>	Acceptable <i>Acceptabel</i>
	'Senga Sengana'	Red <i>Rød</i>	Dark and wrinkled <i>Mørk og rynket</i>	Acceptable <i>Acceptabel</i>
	'Zefyr'	Green tip <i>Grøn spids</i>	Wrinkled <i>Rynket</i>	Unacceptable <i>Uacceptabel</i>
	'Zefyr'	Red <i>Rød</i>	Wrinkled <i>Rynket</i>	Very ripe <i>Meget moden</i>

Table 5. Effect of berry size in cv. 'Elsanta'. Average of storage time. Exp. II. SS=Soluble solids. Acid=Citric acid.
Virkning af bærestørrelse i sorten 'Elsanta'. Gennemsnit af lagertid. Forsøg II. RT=Opløseligt tørstof. Syre=Citronsyre.

Size (g)	Initial berry weight (g)	Weight loss (%) 5 days	Antho- cyanin mg/100 g	SS (%)	Acid g/kg	pH	Vitamin C mg/100 g
<i>Størrelse</i> (g)	<i>Initiel</i> <i>bærvægt</i> (g)	<i>Vægttab</i> <i>pct.</i> <i>5 døgn</i>	<i>Antho-</i> <i>cyanin</i> <i>mg/100 g</i>	<i>RT</i> <i>pct.</i>	<i>Syre</i> <i>g/kg</i>	<i>pH</i>	<i>Vitamin</i> <i>C</i> <i>mg/100 g</i>
6.00-11.99	10	5.1	12	6.4	9.0	3.3	83
12.00-17.99	15	4.0	10	6.5	8.3	3.4	78
18.00-23.99	21	4.1	11	7.3	8.6	3.3	75
LSD	1	n.s.	n.s.	0.5	0.4	n.s.	5

Table 6. Effects of storage time in the cv. 'Elsanta'. Average of berry weight. Exp. II. SS=Soluble solids. Acid=Citric acid.

Virkninger af lagertid i sorten 'Elsanta'. Gennemsnit af bærvægt. Forsøg II. RT=Opløseligt tørstof. Syre=Citronsyre.

Storage days	Initial berry weight (g)	Weight loss (%)	Anthocyanin mg/100 g	Surface colour			SS (%)	Acid g/kg	pH	Vitamin C mg/100 g
	<i>Initial vægt (g)</i>	<i>Vægttab pct.</i>	<i>Anthocyanin mg/100 g</i>	<i>Overfladefarve</i>			<i>RT pct.</i>	<i>Syre g/kg</i>	<i>pH</i>	<i>Vitamin C mg/100 g</i>
<i>Dage på køl</i>	<i>Initial bærvægt (g)</i>	<i>Vægttab pct.</i>	<i>Anthocyanin mg/100 g</i>	<i>L</i>	<i>a</i>	<i>b</i>				
0	16	0.0	8	10	14	9	7.0	8.9	3.2	74
2	15	2.2	9	37	31	24	7.0	8.6	3.3	81
5	15	4.4	12	37	33	23	6.9	8.8	3.4	81
7	15	5.4	15	36	37	28	6.1	8.3	3.4	78
LSD	n.s.	1.0	2	1	2	1	0.7	n.s.	0.1	5

ity was excellent. It was not possible to find any change in appearance or taste in comparison with fresh picked berries in either of the three weight classes after seven days.

The berry size had no great effect on storage parameters (Table 5). The highest content of soluble solids was found in the largest berries and the highest content of vitamin C was found in the smallest ones.

Discussion

An ice bank cooling system ensures a high relative humidity, a fast cooling and a temperature always above 0°C. So, the respiration and the transpiration are quickly decreased in such rooms (3). In exp. I the keeping quality of the four cultivars under these climatic conditions was investigated. By use of Tables 1, 2, and 3 the effects from cultivar, maturity and storage time on certain physical and chemical parameters are presented. Table 4 covers the sensory evaluation. The results from exp. II with the cv. 'Elsanta' are found in Tables 5 and 6.

The berry weights and their relative differences found (Table 1) are comparable with earlier results (2). The maximal weight loss after five days (Tables 1 and 5) was acceptable in both experiments (3). The higher weight loss found in the berries with green tips (Table 2) might as due to a higher osmotic potential or a higher surface to volume ratio as these berries also had a lower soluble solids content. The anthocyanin content was smallest in the cv. 'Elsanta', and greatest in the cv. 'Senga Sengana' (Table 1). This result is in agreement with the differences in internal colour observed in cross sections. However, the anthocyanin content increased in the cv. 'Elsanta' during the storage period

(Table 5). The explanation may be that the maturation is still taking place in these berries even after picking and transfer to dark cooling rooms. The increasing pigment content is like that described in berries on the plant (14). The surface colour differed between the cultivars (Table 1). The observed light red surface colour of the cv. 'Elsanta' and the dark surface colour of cv. 'Senga Sengana' was in agreement with results from cultivar trials (2). The most remarkable difference was the change in the cv. 'Elsanta' after transfer to the cooling room (Table 6). The enhancement in anthocyanin content may explain this difference to some degree.

Berries with green tips might be expected to keep better than ripe ones. This was not confirmed (Tables 2 and 4).

Usually the sensory quality decreases after storage of strawberries (13). This was also observed in experiment no. I. However, in both exp. I and II the sensory quality of the cv. 'Elsanta' decreased so slowly that no change was detectable after 7 days of storage.

Conclusion

The cv. 'Elsanta' was more suitable for storage than the cvs 'Dania', 'Senga Sengana' and 'Zefyr'. Berries with green tips did not keep better than red ones. The berry size in the cv. 'Elsanta' did not explain why this cultivar kept better than the other three cultivars.

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