Fruit Varieties Journal 50(3):160-167 1996

Yield and Quality Attributes of Strawberry Cultivars Grown in Denmark 1990-1991

ULLA KIDMOSE,[1] HELLE ANDERSEN[2] AND OLE VANG-PETERSEN[2]

Abstract

Twelve strawberry cultivars were tested at the Department of Pomology and Vegetables at the Danish Institute of Plant and Soil Science in 1990 and 1991. The chemical composition and physical characteristics were measured and sensory evaluation was carried out at the Department of Food Science and Technology.

Significant differences were found among cultivars for yield, fruit size, soluble solids, titratable acidity, vitamin C, firmness, surface colour and sensory attributes. 'Elsanta,' 'Korona,' 'Polka' and 'Sima' were the only cultivars which gave a good crop and fruit size. 'Polka' and 'Douglas' were sweet cultivars with a strong strawberry flavour; but 'Polka' had a low vitamin C content. 'Dania' and 'Elvira' were very sour cultivars, and 'Elvira' had a high content of vitamin C. 'Hiku,' 'Korona' and 'Elsanta' had low titratable acidity and almost no sourness, and 'Elsanta' had a high vitamin C content.

Introduction

Strawberries have been grown in Denmark for decades, where breeding and testing cultivars has been conducted at the Department of Pomology and Vegetables in Aarslev (1, 12, 13). Some Danish cultivars, such as 'Zefyr' and 'Dania,' are commonly grown in Scandinavia, while 'Sima' is grown to some extent in Germany for PYO. The aim of this research was to compare crop yield and quality characteristics of twelve strawberry cultivars grown in Denmark.

Materials and Methods

Field experiment

Twelve cultivars were tested (Table 2). Three cultivars that have performed well in Holland, three cultivars which originate in the U.S.A., one from Finland, and one from Denmark were evaluated, using the early 'Zefyr,' the midseason 'Elsanta,' the lateseason 'Dania' and as processing reference 'Senga Sengana,' as standard comparisons. Plant material consisted of runners planted in the field 18 July 1989 on a sandy loam. Thirty plants/plot of each cultivar were randomized in 3 blocks. The runners were planted in 25 cm high, two-row, black polythene covered, raised beds and spaced 40 cm between the rows and 30 cm in the rows. The bed was about 90 cm broad, and there was a free space of 80 cm between beds. The water supply was maintained by drip irrigation during dry periods with 2.5 mm water + 50 ppm nitrogen per day from bloom to harvest and again after harvest. The plants were kept for three years, but in the last year many plants died due to an attack of the vine weevil larvae (Otiorrhynchus), which thrives in the climate below the polythene cover.

Time of flowering and runner production is evaluated in 1991. Yield and berry size are evaluated in 1991 and 1992. Samples for sensory evaluation and chemical and physical analysis were harvested twice for each variety in both years.

Sensory evaluation

After harvest one kilogram of fruit was mashed and used for the sensory evaluation. The sensory evaluation was conducted at each harvest time in both years. A taste panel of 8 trained judges evaluated sweetness, sourness and strawberry flavour respectively on a scale of 11 points (0-10). Zero is

[1]Department of Food Science and Technology, Danish Institute of Plant and Soil Science, Research Centre Årslev.
[2]Department of Pomology and Vegetables, Danish Institute of Plant and Soil Science, Research Centre Årslev.

no sweetness, no sourness or no strawberry flavour and 10 is very sweet, very sour or a very strong strawberry flavour.

Chemical analysis

After harvest determination of total vitamin C, titratable acidity and soluble solids was conducted for each harvest time in both years. The analyses were carried out as determinations in duplicate.

For determination of total vitamin C, 200 g of strawberry fruit were extracted with 100 ml of 0.5% oxalic acid in a Waring blender. The blender was purged with nitrogen for 5 min, after which the mixture was homogenized for 5 min. After filtration an aliquot of the extract was treated with DL-homocysteine to reduce dehydroascorbic acid (DHAA) to ascorbic acid (AA) according to Lento et al. (2). After elimination of excess homocysteine with N-ethyl-maleimide, the extract was potentiometrically titrated with 2,6-dichlorophenol-indophenol (5).

For determination of titratable acidity and soluble solids, 200 g of sample was homogenized in a Waring blender with 100 g of water. Soluble solids were determined by refractometry and expressed as g/100g. Titratable acidity was determined by titration with 0.1 N NaOH to pH 8.1, and calculated as g citric acid/100 g.

Physical measurements

After harvest the surface colour was determined using a Hunter colorimeter (CIE-Lab). Twenty-five strawberries were measured three times each at each harvest time in both years. The surface colour was expressed by the L-value, which is the intensity of lightness. After harvest berry firmness was measured with an Instron Universal Testing Machine fitted with a standard 4.8 mm probe. Twenty-five strawberries were measured at each harvest in both years, and firmness was expressed in newtons (N).

Results and Discussion

Field records

Climatic conditions and growth system

In Table I the climatic data for the 1990 and 1991 growing seasons and harvest times are shown. As compared to the long term (1961-90) average. May of 1990 was warm and dry, followed by a very wet June and a normal July. 1991 had a colder May followed by a cold June and then a warm July.

The raised bed with close spacing gives advantages to cultivars with an open, fairly weak, growth habit, and the more porous and airy soil in the raised bed supports cultivars with a weak root system such as 'Elsanta' and 'Korona.' Cultivars with very vigorous and dense growth are at a disadvantage with the close spacing. During flowering some pollination problems can occur, especially in the middle of the plants. If the cultivars are susceptible to grey mould there is a risk of many rotten berries, caused by the high humidity in the plants; one such cultivar is 'Senga Sengana.' These factors should be considered when evaluating these cultivars under the sets of field conditions.

Table 1. Monthly climatic records for Aarslev in 1990 and 1991 compared to a 30-year average. Harvest periods in 1990 and 1991.

	Mean temperature, °C			Precipitation, mm			Harvest date	
Month	1990	1991	Average 1961-90	1990	1991	Average 1961-90	1990	1991
May	12.6	9.1	11.0	4	17	46		
June	14.3	11.5	14.5	113	62	53	6/6-13/7	27/6-26/7
July	15.4	17.0	15.8	46	43	61		

Plant growth

All cultivars were satisfactorily established in the summer and autumn of 1989. The winter 1989/90 was extremely mild and almost without frost, thus in April 1990 the summer planted runners were very vigorous and each plant had several crowns. In Table 2 the cultivars are listed in 3 groups according to plant growth.

Time of flowering and runner production

The flowering began on 16 May with the early standard cultivar 'Zefyr' (Table 3). The date for 10% open flowers ranged in 1991 11 days from 'Zefyr' to 'Dania.' The end of flowering (80% bloom) varied only 3 days from early to late cultivars.

Early flowering cultivars had a longer period of flowering than the late cultivars 'Dania' and 'Sima.'

Season of harvest

The harvest lasted approximately 5 weeks. On the average in Denmark, 'Senga Sengana' ripens around 1 July, and therefore the harvest in 1990 was very early. The date of 50 per cent picked fruits is listed in Table 4 and the cultivars are categorised according to earliness. 'Cardinal' and 'Zefyr' had the earliest harvest in both years, while 'Dania' was consistently the latest. 'Elvira' varied from 1990 to 1991, being classified as early in 1990, but having 50% of its fruit harvested late in 1991.

Yield and berry size

In 1990 the yield was reasonably high even though the average size of the berries was small (Table 5). In 1991 there was only a light crop and a poor berry size for most of the cultivars; presumably due to the cold weather conditions in May and June, and a late removal of leaves in the previous autumn. 'Chandler' and 'Douglas' do not grow well in the Danish climate, possibly due to the colder temperatures. This may also be the case for 'Cardinal' in 1991. 'Senga Sengana' and 'Zefyr' are usually good croppers in Denmark, but failed in this trial. 'Elsanta,' 'Korona,' 'Polka,' 'Sima' and to some extend 'Dania' were the only cultivars which produced a good crop and adequate fruit size.

Chemical Composition

Soluble solids, titratable acidity and vitamin C

A significant difference in soluble solids was found among cultivars in both years (Table 6). As shown in Table 6, 'Cardinal' had the highest content of soluble solids; whereas 'Senga Sengana' had the lowest in both years. The level of soluble solids was in agreement with investigations

Table 2. Plant density, vigor and habit.

Plant density, vigor and habit	Cultivar	Origin of cultivar
Plant density: Open, Strong vigorous growth	'Cardinal'	U.S.A.
	'Elsanta'	Netherlands
Plant density: Medium open, Medium/strong growth	'Chandler'	U.S.A.
	'Elvira'	The Netherlands
	'Korona'	The Netherlands
	'Polka'	The Netherlands
	'Zefyr'	Denmark
Plant density: Dense, Strong vigorous growth	'Dania'	Denmark
	'Douglas'	U.S.A.
	'Hiku'	Finlandia
	'Senga Sengana'	Germany
	'Sima'	Denmark

of Sistrunk & Morris (10), who found a variation between 5.3-8.2% for twenty cultivars grown in North America. Earlier investigations also showed large differences in soluble solids between cultivars; but soluble solids can also be influenced by maturity and climate conditions (3, 4, 7, 9, 10, 11). Cold cloudy weather reduces the content of soluble solids (4). In this trial the content of soluble solids was not particularly affected by the climate conditions (Table 6).

The level of titratable acidity is an important quality parameter for strawberry. According to Sistrunk and Moore (9), the differences in acidity between varieties result in many flavor differences.

Titratable acidity varied significantly among cultivars in both years. The results for titratable acidity, expressed as g citric acid in 100 g of berries, are shown in Table 6. 'Cardinal,' 'Zefyr,' 'Elvira' and 'Dania' had the highest values, whereas 'Korona,' 'Polka' and 'Elsanta' had the lowest values in both years. The level of titratable acidity is in agreement with investigations of Sistrunk and Morris (10), who found a level between 0.71-1.16% for twenty tested cultivars.

Table 3. Date of flowering period and runner production 1991.

Cultivar	Date for 10% bloom	Date for 80% bloom	Runner production number Score 0-3[1]	Runner production length Score 0-3[1]
Zefyr	16/5	8/6	3.0	2.7
Chandler	16/5	8/6	2.7	2.3
Elsanta	17/5	9/6	1.7	1.3
Korona	17/5	7/6	2.0	2.0
Senga Sengana	19/5	8/6	2.0	1.0
Polka	17/5	9/6	2.0	1.3
Douglas	20/5	12/6	3.0	2.7
Cardinal	20/5	11/6	3.0	3.0
Hiku	21/5	9/6	1.0	1.3
Elvira	27/5	14/6	3.0	2.3
Dania	27/5	11/6	1.7	1.3
Sima	28/5	13/6	1.7	2.0

[1]Number: 0 No, 1 Few, 2 Many, 3 Prolific.
Length: 0 No, 1 Short, 2 Long, 3 Very long.

Table 4. Time of harvest.

	Date of 50 percent fruits harvested 1990	1991	Category
Cardinal	15/6	7/7	Very early
Zefyr	19/6	7/7	Very early
Chanlder	21/6	11/7	Early
Elsanta	23/6	11/7	Early
Polka	23/6	11/7	Early
Douglas	24/6	11/7	Early
Korona	25/6	9/7	Early
Elvira	25/6	20/7	Early-midseason
Senga Sengana	28/6	13/7	Midseason
Hiku	30/6	14/7	Midseason
Sima	2/7	16/7	Late
Dania	2/7	21/7	Late

Earlier investigations also showed significant differences in titratable acidity between cultivars; but titratable acidity is also affected by maturity, harvest and climate conditions. Cool, wet harvest seasons increase the acidity (9). In this trial a significant difference in tritratable acidity was found between the years (Table 6). The higher tritratable acidity in 1990 compared to 1991 could be explained by the climate conditions (Table 1). Varieties with favorable a ratio of soluble sugars to titratable acidity are 'Elsanta,' 'Polka' and 'Chandler' (Table 6).

Strawberries are an excellent source of ascorbic acid (vitamin C) seen from a nutritional point of view (4). Variations in the content of vitamin C for the different varieties are for that reason interesting. In this trial the content of vitamin C varied significantly among cultivars in both years. As seen in Table 1 vitamin C content varied between 35-73 mg/100g berries. 'Elsanta,' 'Zefyr' and 'Elvira' had the highest vitamin C content; whereas 'Senga Sengana,' 'Korona,' 'Polka' and 'Hiku' had a low vitamin C content in both years. This is in agreement with earlier investigations (3, 4, 7, 9, 10). Sistrunk & Morris (10) found a variation in vitamin C content of 20-54 mg/100g berries for twenty cultivars.

Table 5. Yield, berry size and rot infected fruits.

	Marketable fruits t/ha		Berry weight g/berry		Grey mould infected fruits as % of total yield	
	1990	1991	1990	1991	1990	1991
Cardinal	18.4	7.2	14	10	0.4	0.1
Chandler	16.9	9.7	11	8	0.3	0.3
Dania	24.5	17.3	11	9	0.9	0.9
Douglas	10.2	7.7	11	9	0.3	0.5
Elsanta	32.6	13.8	13	9	1.0	0.5
Elvira	28.1	13.8	11	10	0.7	1.0
Hiku	13.3	6.3	7	8	2.6	0.6
Korona	32.0	18.6	11	8	2.6	3.0
Polka	27.2	23.1	12	8	1.2	0.8
Senga Sengana	15.8	17.5	8	8	2.3	1.5
Sima	31.1	13.5	6	7	0.4	1.7
Zefyr	12.7	9.0	8	8	0.2	1.4
sign	***	*	***	***	n.s.	n.s.
$LSD_{cultivar}$	3.7	7.1	2	2		

*Indicates significance at 5% level.
**Indicates significance at 1% level.
***Indicates significance at 0.1% level.

Physical Measurements

Colour and firmness

Earlier investigations showed that firmness was greatly influenced by cultivar, maturity and weather conditions (9, 10). If the fruits are harvested at the same degree of maturity, the firmness represents inherent firmness and "resistance" to handling and transportation (4). This trial showed that firmness varied significantly among cultivars (Table 7). 'Cardinal' was the

Table 6. Soluble solids, titratable acidity and vitamin C in 1990 and 1991.

	Soluble solids (g/100g)		Titratable acidity (g/100g)		Ratio soluble solids to titratable acidity		Vitamin C (mg/100g)	
Cultivar	1990	1991	1990	1991	1990	1991	1990	1991
Zefyr	7.0	6.7	1.13	0.85	6.15	7.80	73.7	67.2
Chandler	7.2	7.4	0.86	0.85	8.45	8.73	55.5	55.0
Elvira	6.4	7.0	1.03	0.98	6.26	7.19	68.1	71.3
Cardinal	8.6	8.8	1.11	1.08	7.72	8.20	58.3	57.0
Korona	7.2	6.0	0.83	0.73	8.65	8.22	42.5	39.5
Polka	7.1	6.8	0.86	0.70	8.32	9.77	38.8	39.9
Elsanta	7.4	7.1	0.80	0.76	9.23	9.41	73.5	72.1
Douglas	6.4	8.1	0.98	0.86	6.72	9.50	52.1	61.5
Hiku	7.1	7.3	0.92	0.82	7.68	8.91	33.8	44.2
Senga Sengana	6.4	6.2	0.99	0.88	6.43	7.06	35.9	33.1
Sima	5.3	7.1	0.98	0.88	5.45	8.03	53.0	61.4
Dania	6.7	6.9	1.03	0.94	6.71	7.40	35.9	45.2
Sign	***	*	**	***	*	*	***	**
Mean	6.9	7.1	0.96	0.86	7.31	8.35	51.8	54.0
$LSD_{cultivar}$	0.9	1.3	0.15	0.07	1.82	0.07	8.8	18.9
LSD_{year}	NS		0.03		NS			

*Indicates significance at 5% level.
**Indicates significance at 1% level.
***Indicates significance at 0.1% level.

Table 7. Firmness and surface colour in 1990 and 1991.

Cultivar	Firmness (Newton)		Surface colour (lightness)	
	1990	1991	1990	1991
Zefyr	1.6	1.7	35.2	33.5
Chandler	4.8	3.1	34.4	34.3
Elvira	3.6	2.6	23.3	36.0
Cardinal	6.2	4.6	34.4	35.0
Korona	3.2	5.0	23.5	31.1
Polka	3.8	4.2	36.6	34.6
Elsanta	3.0	2.5	24.5	36.2
Douglas	1.8	1.7	35.5	35.1
Hiku	1.1	1.0	39.9	36.3
Senga Sengana	1.6	1.6	32.7	31.6
Sima	4.1	1.9	34.3	30.7
Dania	2.3	1.6	40.1	36.3
Sign	***	***	***	***
Mean	3.1	2.6	32.9	34.2
$LSD_{cultivar}$	0.4	0.4	3.2	1.4
LSD_{year}	0.1		0.7	

[1]The values are the force in newton, which is required to penetrate a strawberry.
[2]L = lightness, mneasured on a scale from 0 = black to 100 = white on a Hunter colorimeter.
*Indicates significance at 5% level.
**Indicates significance at 1% level.
***Indicates significance at 0.1% level.

firmest cultivar; whereas 'Hiku,' 'Senga Sengana,' 'Zefyr' and 'Douglas' were the softest cultivars in both years.

Earlier investigations regarding the surface colour showed that the L values are satisfactory for measuring the colour of the skin (4, 6). In this trial, surface colour, the lightness, varied significantly among cultivars in both years (Table 7). 'Dania' and 'Hiku' were the lightest cultivars; whereas 'Korona' was the darkest cultivar in both years. No consumer surveys about preference of strawberry colour have been made in Denmark, but according to Simpson, W. G. (8) comparison of instrumental and sensory evaluation of strawberry colour showed that consumers disliked either very dark berries or very light-coloured berries, which were especially unacceptable.

Sensory Evaluation

A significant difference in sweetness, sourness and strawberry flavour was found among cultivars in both years (Table 8). 'Elvira,' 'Senga Sengana,' 'Sima' and 'Dania' were the sourest cultivars; whereas 'Douglas' and 'Polka' were the sweetest. Cultivars with a strong strawberry flavour were 'Douglas' and 'Polka.'

Correlation of the sensory attributes showed, that sweetness was positively correlated with strawberry flavour ($r = 0.69^{***}$) and negatively with sourness ($r = -0.87^{***}$). The scores for strawberry flavour were only significantly correlated to sweetness scores. This is in agreement with earlier investigations. Shamalia et al. (7) also found, that sweetness was positively correlated with strawberry odour ($r = 0.50^{***}$) and negatively to sourness ($r = -0.35^{**}$). Sistrunk and Moore (9) showed, that differences in flavour were also affected by the level of acidity.

Conclusions

The cultivars differed significantly in yield and all the sensory attributes, as well as in soluble solids, titratable acidity, vitamin C content, surface colour and firmness. 'Elsanta,' 'Korona,' 'Polka,' 'Sima' and to some extent 'Dania' were the only cultivars which gave reasonable crop and fruit size. 'Senga Sengana' and 'Zefyr' are usually good croppers in Denmark but failed in this trial. 'Polka' and 'Douglas' were sweet cultivars with a strong strawberry flavour; but 'Polka' had a low content of vitamin C. 'Dania' and 'Elvira' were very sour cultivars; but 'Elvira' had a high content of vitamin C. 'Dania' had a light surface colour. 'Hiku,' 'Korona' and 'Elsanta' had low titratable acidity and no sourness; but 'Elsanta' had a high content of vitamin C.

The highest yielding varieties are also considered the most fitted for Danish conditions. 'Elsanta' has a most attractive appearance, glossy and bright in color and with a long shelf life. Picked too early the taste is unfortunately almost lacking. For that

Table 8. Sensory attributes for mashed strawberry in 1990 and 1991.

Cultivars	Sweetness[1]		Sourness[2]		Strawberry flavour[3]	
	1990	1991	1990	1991	1990	1991
Zefyr	4.3	5.3	7.1	5.0	5.2	5.1
Chandler	5.5	5.1	5.0	5.4	5.4	5.2
Elvira	3.8	3.8	7.0	7.3	3.8	4.8
Cardinal	6.1	3.1	5.7	7.4	6.3	4.5
Korana	7.0	4.4	3.8	4.9	6.3	3.7
Polka	7.5	6.0	3.4	3.9	6.7	5.0
Elsanta	5.9	5.1	4.5	4.5	5.3	4.6
Douglas	6.1	6.2	4.5	4.6	6.1	6.3
Hiku	5.4	6.1	5.2	4.3	5.7	5.9
Senga Sengana	4.7	3.8	6.5	6.7	5.7	4.5
Sima	3.6	4.3	6.9	6.1	3.9	4.8
Daina	4.1	4.0	7.0	6.2	4.4	4.6
Sign	***	***	***	***	***	***
Mean	5.3	4.8	5.5	5.5	5.4	4.9
$LSD_{cultivar}$	0.9	1.1	0.9	1.0	0.9	1.0
LSD_{year}	0.3		NS		0.3	

[1]On a scale from 0-10. Zero = no sweetness, 10 = very sweet.
[2]On a scale from 0-10. Zero = no sourness, 10 = very sour.
[3]On a scale from 0-10. Zero = no strawberry flavour, 10 = strong strawberry flavour.
*Indicates significance at 5% level.
**Indicates significance at 1% level.
***Indicates significance at 0.1% level.

reason 'Korona' is recommended for local markets and PYO; somewhat dark in color, but with a good taste and texture. In a smaller scale also 'Dania' can be recommended for fresh consumption, but the taste is fresh-sour. Neither 'Elsanta' nor 'Korona' are suitable for freezing or processing. For that purpose 'Senga Sengana' or 'Polka' have to be recommended.

Literature Cited

1. Andersen. H. and A. Thuesen. 1989. Evaluation of strawberry varieties 1987-88. Tidsskr. Planteavl 93:349-358.
2. Lento, H. G., C. E. Daugherty and A. E Denton. 1963. Ascorbic acid measurement. Polarographic determination of total ascorbic acid in foods. J. Agric. Food Chem. 11:22-26.
3. MacLachlan, J. and R. Gormley. 1974. Assessment of field performance and fruit quality of a range of strawberry clones. J. Sci. Fd. Agric. 25:165-177.
4. Nelson, J. W., B. H. Barritt and E. R. Wolford. 1972. Influence of location and cultivar on colour and chemical composition of strawberry fruit. Technical Bulletin 74, Washington, Agricultural Experiment Station.
5. Pongracz, G. 1971. Neue potentiometrische Bestimmungsmetode für Ascorbinsaüre und deren Verbindungen. Z. Anal. Chem. 253: 271-274.
6. Shah, J. N. and O. J. Worthington. 1953. Comparison of several methods and instruments for specifying the color of frozen strawberries. Food Technology 8:121-125.
7. Shamaila, M., T. E. Baumann, G. W. Eaton, W. D. Powrie and B. J. Skura. 1992. Quality attributes of strawberry cultivars grown in British Columbia. Journal of Food Science 57:636-699, 720.
8. Simpson, W. G. (1980). Physical and chemical characteristics of strawberries as an indication of processing quality. Annual Report, Research Station, Kentville, Nova Scotia, pp. 251-258.
9. Sistrunk, W. A. and J. N. Moore. 1971. Strawberry quality studies in relation to new variety development. Bulletin 761, Agricultural Experiment Station, Division of Agriculture, University of Arkansas, Fayetteville.
10. Sistrunk, W. A. and J. R. Morris. 1985. Strawberry Quality: Influence of cultural and environmental factors. In: Evaluation of Quality of Fruits and Vegetables. AVI Publishing Co. Westport, Conn.
11. Skrede, G. 1980. Strawberry varieties for industrial jam production. J. Sci. Food Agric. 31:670-676.
12. Thuesen, A. 1981. Evaluation of strawberry varieties 1978-79. Tidsk. Planteavl 85:235-244.
13. Thuesen, A. 1985. Strawberry variety trials 1982-83 Tidskr. Planteavl 89:171-184.