

Quality attributes of strawberry varieties suitable for mechanical harvest

Kvalitetssegenskaber hos jordbærsorter til maskinhøst

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Summary

A method for determination of the mechanical stability of strawberries has been developed.

The method has been applied for measurement of the mechanical stability of varieties of strawberry suitable for mechanical harvest and varieties which are normally picked by hand.

The varieties 'Mimek' and 'Primek' are very suitable because of high mechanical stability and because jam containing many whole fruits can be processed from them.

The contents of anthocyanins in 'Mimek',

'Primek' and 'Sima' were equal to or higher than the content in 'S. Sengana' and jam processed from these varieties had a good flavour. The quality attributes such as the content of soluble solids and titratable acidity varied greatly. This may be corrected for by proper use of sugar and citric acid during processing. Among the varieties suitable for mechanical harvest 'Primek' and 'Sima' had a high content of vitamin C, about the same level as that of imported fruits of 'Chandler' and 'Douglas'. The content of vitamin C were low in 'Mimek' and 'Senga Sengana'.

Key words: *Fragaria ananassa*, strawberries, mechanical stability, anthocyanins, soluble solids, titratable acidity, jam.

Resumé

Der er udarbejdet en metode til bestemmelse af jordbærs mekaniske stabilitet. Metoden er blevet anvendt til at vurdere maskinhøstbare jordbærsorters anvendelighed til fremstilling af syltetøj med hele jordbær. Sorterne 'Mimek' og 'Primek' er særdeles anvendelige, fordi jordbærrene tåler mekanisk påvirkning særdeles godt.

Det vil være muligt at fremstille syltetøj med mange hele frugter, hvis disse sorter anvendes.

De maskinhøstbare sorters øvrige kvalitets-

egenskaber er også blevet bestemt. Syltetøj fremstillet af 'Mimek', 'Primek' og 'Sima' havde en tilfredsstillende smag. Indholdet af anthocyaniner var som for 'Senga Sengana'.

Indholdet af titrerbar syre og opløseligt tørstof varierer betydeligt, men dette kan der korrigeres for ved forarbejdningen. Af de maskinhøstbare sorter havde 'Primek' og 'Sima' et højt indhold af C-vitamin på samme niveau som i importerede frugter af 'Chandler' og 'Douglas'. Indholdet af C-vitamin var lavt i 'Mimek' og 'Senga Sengana'.

Nøgleord: *Fragaria ananassa*, jordbær, mekanisk stabilitet, anthocyanin, opløseligt tørstof, titrerbar syre, syltetøj.

Introduction

The increasing labour costs involved in picking strawberries has given rise to a large research programme for breeding and selection of varieties suitable for mechanical harvest (48).

Important quality attributes of strawberry jam are flavour, colour and presence of whole fruits. The flavour depends on the contents of aroma substances and the contents of soluble solids such as sugars and titratable acid. Surface colour is determined by the amount and stability of the anthocyanins. The presence of whole fruits in the jam depends on the mechanical stability of the strawberries.

The aim of this paper is to determine the most important quality attributes of strawberry varieties suitable for mechanical harvest.

The consumer wants whole fruits in the jam. Therefore a method for the determination of the mechanical stability of strawberries has been developed. The possibilities of increasing the whole fruit content of strawberry jam using different treatments has been evaluated.

Materials and methods

Fruits

Frozen strawberries of several varieties grown at the Institute of Vegetables and samples of imported strawberries were analyzed and tested for mechanical stability.

Analysis

Methods for determination of the content of soluble solids, titratable acids and anthocyanins has been described earlier (19).

Titratable acidity was calculated as citric acid and the content of anthocyanins as cyanidin-3-glucoside.

Canned strawberries

Drained weight of the canned strawberries were determined by use of a standard sieve (ASTM E11, 2.80 mm aperture) and a draining time of 3 minutes.

The vitamin C content was determined by use of the dichlor-indophenol titration method.

Fig. 1 shows the rotavapor used for the determination of the mechanical stability of the strawberries for processing of canned strawberries.

450 g of a 50 w/w% sugar (commercial quality) solution were transferred to the flask. After rotation for five minutes temperature equilibrium was

Table 1. Treatment time and vacuum.
Behandlingstid og vakuüm.

	min					
	0	10	20	30	40	50
mm Hg	5	100	200	300	400	500

obtained and frozen or pretreated strawberries (150 or 200 g) were added. Increasing vacuum was established as shown in Table 1.

After each stage of vacuum increment normal pressure (1 atm) was established by vacuum release.

After the last treatment period of 10 minutes the content of the flask and the distillate were transferred to 580 cm³ jars. One ml 20 w/w% sodium benzoate (Merck p.) and one ml 10 w/w% potassium sorbate (Struers p.) were added and

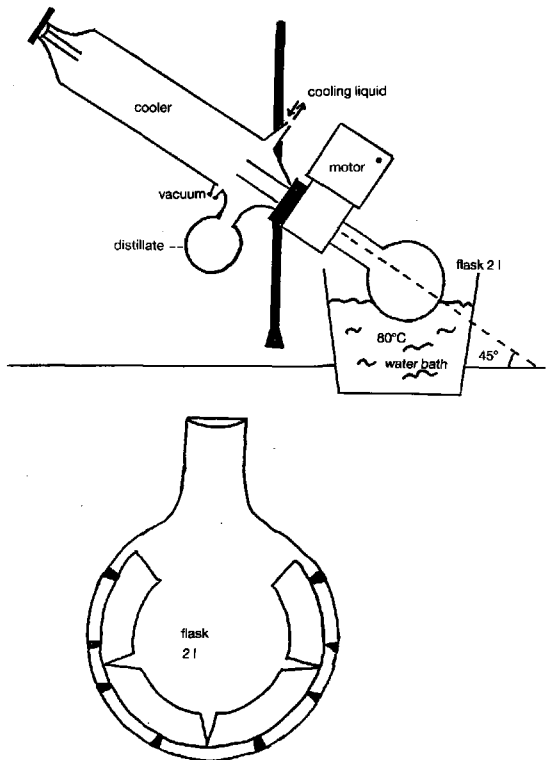


Fig. 1. Equipment for determination of mechanical stability of strawberries.

Udstyr til bestemmelse af jordbærs mekaniske stabilitet.

the jars were closed and cooled in running tap water. For each variety or experimental level, two jars were processed.

After storage of the jars at 12°C for proper time the weight of whole fruits in each jar were determined.

In some experiments a slightly different method of processing were carried out as described below.

Jam

Jam was processed from 900 g strawberries, 900 g sugar and 7.2 g pectin (LM 101 AS). The frozen strawberries were heated to 30°C and pH was adjusted to 3 by use of 50 w/w% citric acid (Merck p.a.) solution. After heating to boiling point the pectin mixed with 20 g of the sugar was added. The remaining part of the sugar was added after repeated heating and the jam was canned in 580 cm³ jars. Cooling of the jars was carried out in running tap water and the jars were stored at 12°C.

Experiment 1

To five 200 g samples of frozen strawberries 0, 50, 100, 200 or 300 gram of sugar was added. After storage at 3°C for 4 days water (80°C) was added and canned strawberries were processed by vacuum treatment (max. 500 mm Hg) as described above.

Experiment 2

Frozen strawberries ('Senga Sengana') were graded by size and weight (Table 2). Canned strawberries were processed by use of vacuum until 300 or 500 mm Hg. By processing 150 g frozen fruits were added to 450 g of a 50 w/w% sugar solution (80°C).

Experiment 3

200 g frozen strawberries of nine varieties were gently mixed with 225 g sugar and then stored at 3°C for 4 days. After addition of 225 g water (80°C) canned strawberries were processed (max. 500 mm Hg).

Experiment 4

Frozen strawberries of eight varieties were applied for processing of canned strawberries and jam. Analyses for soluble solids, titratable acid and anthocyanin content were carried out immediately before processing.

By processing of canned strawberries 150 g of

frozen fruits were added to 450 g of a 50 w/w% sugar solution (70°C).

Experiment 5

Strawberries ('Mimek', 'Primek', 'Senga Sengana', 'Sima') grown in Denmark and imported ('Chandler', 'Douglas') were analyzed for quality attributes. Canned strawberries were processed, as described for experiment 4.

Organoleptical evaluation

Eleven trained panelists evaluated the jam for flavour and fruit firmness using hedonic scales with 10 points for a very strong strawberry flavour or very firm strawberries.

Results

Fig. 2 shows the results of experiment 1. By storage of strawberries before cooking with an increasing amount of sugar the weight of the whole strawberries increased. The greatest effect was

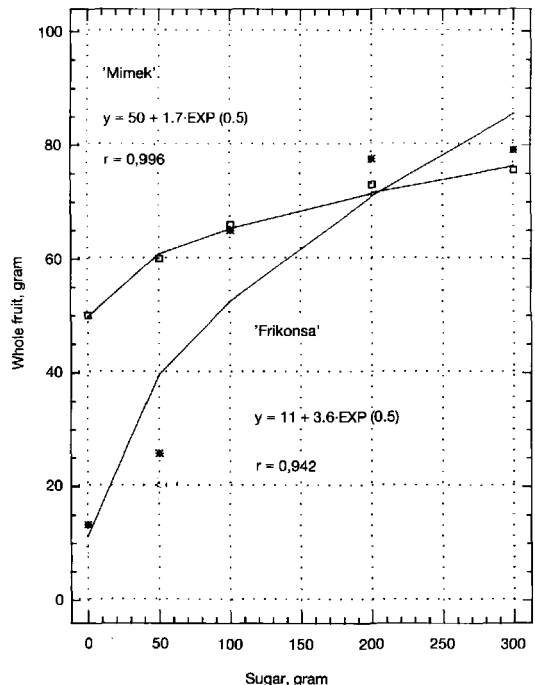


Fig. 2. Whole fruits after storage of 5 samples of 200 g of strawberries with 0, 50, 100, 200 or 300 g of sugar at 3°C for 4 days. Experiment 1 (1984).

Procent hele frugter efter lagring af 5 portioner jordbær på 200 g jordbær med 0, 50, 100, 200 eller 300 g sukker ved 3°C i 4 døgn. Forsøg 1 (1984).

Table 2. Results from an experiment with use of 'Senga Sengana' graded by weight and size. Experiment 2 (1984).

Resultater fra et forsøg med anvendelse af sorterede 'Senga Sengana'. Forsøg 2 (1984).

Diam. Diam. mm	Weight (g) Vægt (g)	max maks. mm Hg	mm Hg
		500	300
		Percentage w/w% whole fruits <i>Procent w/w% hele frugter</i>	
20-27	<= 5	39	85
-	> 5	30	69
> 27	6-9	0	58
-	10-20	0	51
-	> 20	0	0

obtained using the variety 'Frikonsa' which was more susceptible to mechanical damage than 'Mimek'. At a low sugar amount or even without addition of sugar 'Mimek' had a high stability.

The effect of size grading of 'Senga Sengana' was determined in experiment two (Table 2).

Even small fruits of 'Senga Sengana' were very susceptible to degradation. Only by use of very small fruits and a low vacuum a high percentage of whole fruits were obtained.

Strawberries of different varieties varied greatly with respect to mechanical stability. Table

Table 3. Percentage fruits of nine varieties treated in 50 w/w% sugar solution. Experiment 3 (1984).

Procent hele frugter af ni sorter behandlet i 50 w/w% sukker opløsning. Forsøg 3 (1984).

Variety Sort	g/fruit g/frugt	Whole fruits, w/w% Hele frugter, w/w%
'Dania'	7.5	4
'Felicia'	4.6	50
'Frikonsa'	4.3	79
'Induca'	8.8	5
'Korona'	9.7	17
'Mimek'	4.1	84
'Senga Sengana'	4.9	28
'Sima'	8.3	25
'Zefyr'	9.1	0

3 shows the percentage whole fruits after treatment of fruits of nine varieties in 50 w/w% sugar solution until a vacuum of 500 mm Hg.

Only by use of 'Frikonsa' and 'Mimek' an acceptable percentage of whole fruits were obtained.

Table 4 shows the results from determination of mechanical stability and organoleptical evaluation of jam processed from eight strawberry cultivars.

The highest percentage of whole fruits were obtained by use of 'Mimek'. Next to 'Mimek' a high

Table 4. Percentage whole fruits after canning and flavour and firmness of fruits in jam processed from eight strawberry varieties. Experiment 4 (1985).

Procent hele frugter i syltede jordbær samt smag og fasthed på jordbær i syltetøj fremstillet af otte jordbærsorter. Forsøg 4 (1985).

Variety Sort	Canned fruits Whole fruits w/w% <i>Hele frugter w/w%</i>	Jam	
		Flavour <i>Smag</i>	Fruit firmness <i>Frugtfasthed</i>
'3643/78'	61	4.7	5.7
'3656/78'	48	4.4	5.4
'3869/78'	36	4.6	5.8
'1915/79'	57	5.4	5.5
'Mimek'	83	4.6	5.6
'Primek'	61	4.0	5.9
'Senga Sengana'	23	5.0	5.0
'Sima'	36	4.4	5.3
LSD	7	0.7	0.7

Table 5. Content of soluble solids, titratable acid and anthocyanin in eight varieties of strawberry. Experiment 4 (1985).

Indhold af opløseligt tørstof, titrerbar syre og anthocyaniner i otte jordbærsorter. Forsøg 4 (1985).

Variety Sort	Soluble solids <i>Opl. tørstof</i> g/100 g	Titratable acid <i>Titrerbar syre</i> g/kg	Anthocyanin <i>Anthocyanin</i> mg/100 g
'3643/78'	9.3	7.5	51
'3656/78'	9.4	6.9	51
'3869/78'	7.8	10.2	52
'1915/79'	10.8	9.1	51
'Mimek'	8.4	7.5	48
'Primek'	9.7	8.4	52
'Senga Sengana'	8.1	10.2	45
'Sima'	8.7	8.0	62
LSD	0.7	1.6	19

percentage of whole fruits were obtained by use of 'Primek', '3643/78' and '1915/79'.

Results from the determination of the content of soluble solids, titratable acids, and anthocyanin in eight varieties of strawberries are shown in Table 5. The figures are averages from analyses of samples from three harvest days of each variety.

Varieties grown in Denmark ('Mimek', 'Primek', 'Sima', 'Senga Sengana') and imported frozen strawberries ('Chandler', 'Douglas') were tested for mechanical stability and analyzed for important quality attributes (Table 6).

Only by use of 'Mimek' and 'Primek' acceptable levels of 81 and 70 w/w% whole fruits were obtained.

Discussion

The strawberry 'fruit' is the succulent receptacle carrying the true fruits (achenes). *Jewel et al.* (18) has described the cells of the epidermis, hypodermis, cortex, pith and vascular bundles. The most stable tissues are the epidermis and the vascular bundles which even remain after boiling of jam (18).

The strength of the vascular bundles and of the bindings between the cells in the tissues undoubtedly are of great importance for the strength and mechanical stability of the strawberries. Increasing cell volume and decreasing adhesion or few crosslinks between the cells have a decreasing effect on the mechanical stability or the firmness of the strawberries (27, 50, 51).

Table 6. Percentage whole fruits w/w%, soluble solids, titratable acid, anthocyanin and vitamin C for strawberries grown in Denmark and other countries. Experiment 5 (1988).

Procent hele frugter w/w%, opløseligt tørstof, titrerbar syre, anthocyanin og vitamin C for importerede og dansk dyrkede jordbær. Forsøg 5 (1988).

Variety Sort	Whole fruits w/w % <i>Hele frugter w/w pct.</i> g/100 g	Soluble solids <i>Opl. tørstof</i> g/kg	Titratable acid <i>Titrerbar syre</i> mg/100 g	Anthocyanine <i>Anthocyanin</i> mg/100 g	Vitamin C <i>Vitamin C</i>
'Chandler'	10	7	9.5	67	53
'Douglas'	0	8	8.9	46	49
'Mimek'	81	9	6.5	54	34
'Primek'	70	8	8.3	66	47
'Senga Sengana'	9	7	7.3	54	28
'Sima'	35	9	9.3	63	42
LSD	10	2	0.8	9	10

Calcium ions (Ca^{2+}) occur between the cells in the middle lamella where they form ionic crosslinks between carboxylic groups of pectin molecules (2, 5, 27). If sufficient carboxylic groups are present addition and infiltration of calcium, pectin and sugars increases the firmness of the strawberries (3, 4, 16, 22, 25).

Demethylation by the enzyme pectin methyl esterase which occurs in maturing strawberries is of great importance for the firmness because crosslinks between carboxylic groups are made possible by the activity of this enzyme (2, 5, 17).

Another reason for variations in fruit firmness or mechanical stability can be different activity levels of the enzyme polygalacturonase, which depolymerizes pectins (15).

By increasing firmness a greater mechanical stability is obtained. A stronger strawberry also could be a result of thicker cell walls and a middle lamella with a high content of cellulose and lignins.

As mentioned before to the consumer whole fruits are of great importance. The method described above are useful to evaluate the mechanical stability of strawberry varieties and to determine the effect of different treatments with reasonable statistical significance (Tables 4 and 6).

The varieties 'Mimek' and 'Primek' suitable for mechanical harvest (48) are also useful for processing of jam with whole fruits. Other small fruited varieties such as 'Frikonsa' also are useful for this purpose. Large fruited varieties such as 'Dania', 'Induca', 'Korona' and 'Sima' are more susceptible to breakdown during processing.

Size grading of large fruited varieties and use of the small sizes for processing of jam is not a very effective method to obtain jam with more whole fruits (Table 2). To obtain whole fruits in jam processed from 'Senga Sengana' the vacuum had to be kept below 300 mm Hg.

On an average 100 g strawberries contain 9 g soluble solids, 6.4 g sugars (sucrose, fructose, glucose), 1 g titratable acids (citric acid, malic acid) 59 mg vitamin C and 0.6 g ashes, but large variations occur (1, 6, 7, 10, 11, 26, 29, 31, 33, 36, 41, 42, 45, 49, 53). The results shown in Tables 5 and 6 are in accordance with the values found in the literature.

During maturation the contents of total dry matter, phenols, chlorophylls, cellulose, protopectin and acids decreases, while the contents

of sugars, anthocyanins, aroma substances and soluble pectins increases (12, 23, 26, 36, 37, 44, 51).

The colour of strawberry products depends on the content of the anthocyanins pelargonidin-3-glucoside and cyanidin-3-glucoside (20, 30, 32, 43). The results from determination of the anthocyanin content (Tables 5 and 6) are in accordance with earlier results (8, 21, 25, 26, 35, 38, 40, 43, 44, 45, 46, 52).

The reason for differences in flavour of jam processed from different varieties can be variation in the content of aroma substances (9, 13, 14, 34, 49).

Because of once-over harvest by mechanical harvest green and partly red fruits are harvested together with mature strawberries. If non-mature strawberries are used for processing of jam a product with an unsatisfactory flavour, and a low content of anthocyanins, vitamin C, and soluble solids is obtained (24, 28, 39, 44).

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