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# Storage and Shelf-Life of Apples grown in Norway II. Effects of controlled atmosphere storage on 'Summerred'

## Lagerung und Haltbarkeit von Äpfeln produziert in Norwegen II. Der Einflub der Lagerung in kontrollierter Atmosphäre auf die Sorte 'Summerred'

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## Summary

Apples of the cultivar 'Summerred', grown in Norway (59°40'N), were harvested in September and stored in controlled atmosphere (CA) at 3 % $O_2$ + 3 % $CO_2$ or in normal air (NA) at 2 °C until the middle of January. After removal from storage in December and January, the apples were kept one week at room temperature, simulating shelf-life. There were only small or no differences in fruit quality between the two storage methods. Principal component analysis (PCA) of shelf-life samples revealed three components explaining 87 % of the total variation. The most important cause of variation were the storage methods (41% explained), followed by storage period (31% explained) and the variation caused by year of harvest (15 % explained).

Beneficial effects of CA-storage for 'Summerred'-apples were of minor importance and therefore they cannot justify the cost of CA-storage

## Zusammenfassung

Im Südosten Norwegens (59° 40'N) angebaute Äpfel der Sorte 'Summerred' wurden im September geerntet und in kontrollierter Atmosphäre (CA) bei 3 % $O_2$ und 3 % $CO_2$ oder im Normallager bei 2 °C (±1°C) bis Mitte Januar gelagert. Proben wurden sowohl im Dezember als auch im Januar entnommen, um die Qualitätseigenschaften sowohl zur Auslagerung als auch nach einer Woche Aufbewahrung bei Raumtemperatur, festzuhalten. Die Principal Component Analyse (PCA) ergab, daß drei Komponenten 87 % der gesamten Variation erklären. Die Lagerungsmethode war die wichtigste Ursache (erklärte 41%), gefolgt von der Lagerungsperiode (erklärte 31%) und die Variation mit den Versuchsjahren erklärte 15 %. Der festgestellte geringe qualitätsverbessernde Effekt der CA-Lagerung für die Sorte 'Summerred', kann die Mehrkosten, im Vergleich zur Kühllagerung, nicht verantworten.

## Introduction

Climate plays an important role for fruit quality, especially as one approaches the climatic limits for fruit production. An important apple cultivar suitable for the climatic conditions in Norway is 'Summerred'. The harvest season for 'Summerred' is medium early; i.e. the last part of August and the beginning of September in the United Kingdom (SMITH 1971). Under Norwegian growing conditions, optimal harvest time is usually in the middle of September. In southern European countries like Switzerland 'Summerred' is usually stored until the end of October at ordinary 2–4 °C cold store (HUSISTEIN and GREMMINGER 1986), while in Norway it is stored until November/December (LANDFALD 1980). CA-storage has resulted in improved quality in several apple cultivars, but only a few of the cultivars grown in Norway have been tested.

MEBERG et al. (2000) showed that CA-storage of Norwegian grown 'Aroma' was beneficial. However, no information on CA-storage of 'Summerred' was available. Climatic conditions such as temperature, light and precipitation during the growing season may have consequences on the physiological development and quality of fruits (KVÅLE 1969), which again may effect the results of CA-storage treatments.

The aim of the investigation was: To show the response of CA-cold storage on an early maturing apple cultivar grown in cool climate, to simulate shelf-life by keeping stored apples one week at room temperature in normal air and thereafter treat the data by means of multivariate methods such as Principal component analysis (PCA), to show features in a complex set of data that cannot be obtained by univariate methods

## Materials and methods

Apples of the cultivar 'Summerred' were harvested in the south-eastern part of Norway (59°40'N) at approximately the optimum harvest time (in September) from 8–13 year old trees. The mean temperature from May to September was approximately 12–14 °C. No postharvest chemical treatments were used. Only first quality apples were used in the trials (NORWEGIAN STANDARD, NS 2801, 1986). The samples were placed in extruded polystyrene boxes or polyethylene string bags. Fruit weight was assessed at start and during the experiment. As optimal CA-conditions for 'Summered' were unknown, a storage regime of 3 % $O_2$ + 3 % $CO_2$ was established, because such conditions showed to be relatively safe for most apple cultivars (HARDENBURG et al. 1986). The actual CA-conditions were 3–4 % $O_2$ + 3 % $CO_2$, while NA-conditions were 21% $O_2$ + 0.5–1% $CO_2$. A computerised small scale system for CA-storage experiments, (MEBERG et al. 2000), was used.

Table 1. Effects of controlled atmosphere (CA) storage versus normal air (NA) storage. Years and storage period effects on quality parameters for Norwegian grown 'Summerred'. Repeated measurements after shelf-life trials (one week at 20 °C). All results are given on fresh weight basis. SS = soluble solids, TA = titratable acidity.
*Der Einfluß der CA-Lagerung verglichen mit Normallagerung (NA). Versuchsjahre und Lagerdauer beinflussen die Qualitätseigenschaften der in Norwegen produzierten Sorte 'Summerred'. Wiederholte Messungen nach der Nachlagerung (eine Woche bei 20°C). Alle Ergebnisse bezogen auf das Frischgewicht. SS = soluble solids, TA = titratable acidity.*

| MAIN STORAGE | Soluble Solids (%) | Titrat. Acidity (%) | SS/TA | pH | L-asc. acid (mg/100g) | Ground colour (1–8) | Sensory scores (1–9) | Weight loss (%) | Firmness (kg/cm²) | Rot incidence (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| CA | 11.5 | 0.7 | 17.1 | 3.3 | 12.1 | 6.7 | 5.2 | 0.6 | 6.4 | |
| NA | 11.6 | 0.7 | 19.2 | 3.3 | 12.7 | 7.2 | 5.2 | 0.7 | 6.2 | |
| Level of significance | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | |
| Start value | 11.8 | 0.9 | 12.8 | 3.1 | 15.2 | 6.9 | 5.6 | 0.0 | 8.0 | |
| Period 2 | 11.4 | 0.6 | 18.6 | 3.3 | 11.8 | 7.0 | 5.5 | 0.7 | 5.8 | |
| Period 3 | 11.5 | 0.5 | 23.2 | 3.4 | 10.3 | 6.9 | 4.7 | 1.2 | 5.1 | |
| Level of significance | n.s. | *** | *** | *** | * | n.s. | * | *** | *** | |
| Year 1993 | 10.9 | 0.6 | 18.6 | 3.3 | 15.0 | 6.3 | 4.7 | 0.8 | 6.9 | |
| Year 1994 | 12.9 | 0.7 | 19.8 | 3.3 | 12.8 | 7.8 | 5.6 | 0.5 | 6.2 | |
| Year 1995 | 10.8 | 0.7 | 16.2 | 3.3 | 9.6 | 6.8 | 5.4 | 0.6 | 5.8 | |
| Level of significance | * | n.s. | n.s. | n.s. | * | n.s. | * | n.s. | * | |
| SHELF-LIFE | | | | | | | | | | |
| CA | 11.6 | 0.5 | 22.6 | 3.4 | 11.7 | 7.5 | 4.3 | 3.9 | 4.6 | 17.1 |
| NA | 11.2 | 0.4 | 27.2 | 3.5 | 10.2 | 7.9 | 4.2 | 4.2 | 4.4 | 29.4 |
| Level of significance | n.s. | n.s. | * | * | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. |
| Period 2 | 11.7 | 0.5 | 21.8 | 3.4 | 11.6 | 7.7 | 4.9 | 4.1 | 4.8 | 9.8 |
| Period 3 | 11.1 | 0.4 | 27.9 | 3.5 | 10.4 | 7.7 | 3.6 | 4.0 | 4.2 | 36.6 |
| Level of significance | * | *** | ** | ** | n.s. | n.s. | * | n.s. | *** | * |
| Year 1993/94 | 11.0 | 0.4 | 26.9 | 3.4 | 10.9 | 7.6 | 4.1 | 4.1 | 5.3 | 5.4 |
| Year 1994/95 | 12.9 | 0.5 | 27.8 | 3.5 | 14.2 | 8.5 | 3.6 | 5.1 | 4.5 | 34.0 |
| Year 1995/96 | 10.4 | 0.5 | 20.0 | 3.4 | 7.9 | 7.1 | 5.0 | 3.0 | 3.8 | 30.4 |
| Level of significance | n.s. | n.s. | * | n.s. | ** | * | n.s. | ** | ** | n.s. |

Storage temperature was 2 °C (±1°C) and relative humidity was 95–100 %. The experiment was terminated in January all three years. The first storage period was terminated in the first part of December and the second storage period was terminated in the last part of January. At each sampling date, 24 apples were removed from each treatment with 12 fruits analysed within two days for quality parameters. The remaining 12 fruits were stored for another week simulating shelf-life (20 °C (±1°C), 25–30 % RH), and thereafter analysed. The quality parameters firmness (kg/cm²), ground colour (scores 1–8), sensory taste (preference, scores 1–9), soluble solids (SS, %), pH, titratable acidity (TA, % malic acid), starch (starch iodine test, scale 0–5), L-ascorbic acid (mg/100 g fresh weight, HPLC), observations of shrinkage symptoms, general impression, rot incidence (% apples with rot spots) and weight loss (%) were analysed as described by MEBERG et al. (2000).

To get an overview of the main results, principal component analysis (PCA), (Unscrambler, version 6.11) was applied. The PCA is a bilinear modelling method giving an interpretable overview of the main information in a multi-dimensional data table. All attributes were mean centred and scaled to unit variance prior to analysis. The calibration model was validated by full scale cross validation. To detect significant differences the data were subjected to analysis of variance. Storage seasons were used as replicates.

## Results and discussion

### *Main storage*

Generally, fruit weight and firmness decreased significantly throughout the experiment. The total weight loss at the end of storage was less than 1.2 %. Ground colour remained stable during storage. Starch content was low at the time of harvest (scores 1–2) and no starch was detected by December in either apples stored in CA (CA- apples) nor in apples stored in NA (NA-apples). The SS/TA-ratio and pH increased significantly, while titratable acidity, sensory scores and L-ascorbic acid concentration decreased significantly during storage. Storage method had no significant effect on the measured quality factors (Table 1).

### *Shelf-life trials*

A significantly higher SS/TA-ratio and pH was found in NA-apples compared to CA-apples, after shelf-life storage, but storage method did not effect the other measured quality factors. A significantly higher amount of apples with rot spots was found in January compared to December. The ratio SS/TA and pH was higher, while firmness, sensory scores, soluble solid- and titratable acidity content in apples from shelf-life trials in January were significantly lower than apples from shelf-life trials in December.

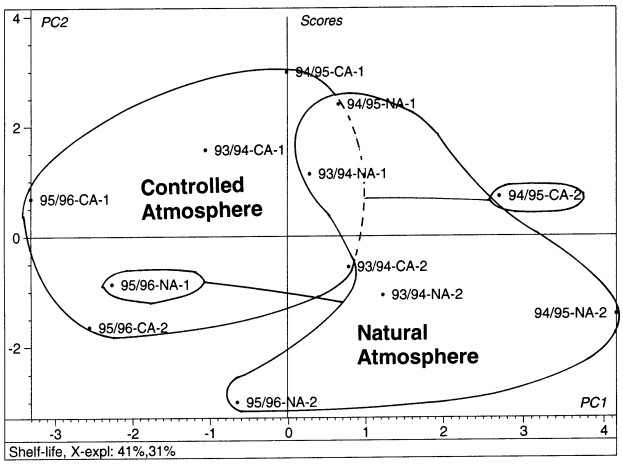



Fig. 1A. PCA score plot for principal component (PC) 1 and 2 for shelf-life trials. Sample signatures: 93/94 = year, NA = normal air, CA = controlled atmosphere, 1–2 = storage period. The plot shows the samples being related either to CA or NA. *PCA plot Zeichenfläche für Komponenten (PC) 1 und 2 für die Nachlagerung bei Raumtemperatur. Probenbenennungen: 93/94 = Versuchsjahr, NA = Normallager, CA = CA-Lager, 1–2 = Zeitpunkt der Probennahme aus dem Lager. Das Plot zeigt die Proben für CA und NA.*

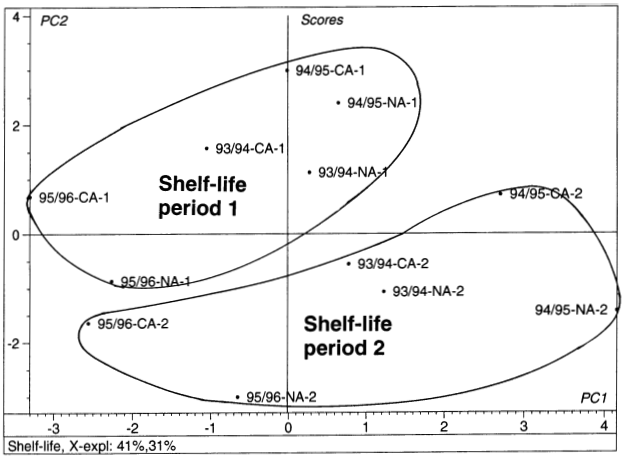



Fig. 1B. PCA score plot for principal component (PC) 1 and 2 for shelf-life trials. Sample signatures: 93/94 = year, NA = normal air, CA = controlled atmosphere, 1–2 = storage period. The plot shows the samples being related either to storage period 1 or 2. *PCA plot Zeichenfläche für Komponenten (PC) 1 und 2 für die Nachlagerung bei Raumtemperatur. Probenbenennungen: 93/94 = Versuchsjahr, NA = Normallager, CA = CA-Lager, 1–2 = Zeitpunkt der Probennahme aus dem Lager. Das Plot zeigt die Proben der Lagerungsperiode 1 und 2.*

The effect of shelf-life was summarised by means of PCA, showing three interpretable components which explained 87 % of the total variation. PC1, showing the most important information in the data to be the differences between the two storage treatments, CA and NA, explaining 41% of the total variation (Figure 1A, and C). This feature does not become apparent in the ANOVA. Taste (sensory scores), TA and firmness were variables mainly being related to CA, while variables mostly related to NA were SS, L-ascorbic acid, weight loss, ground colour rotting, pH and the ratio SS/TA. There was some overlapping of samples belonging to the CA and NA side.

Another feature clearly shown by means of PCA are the differences between the first and the second storage period explaining 31% of the total variation (Figure 1B and C). Variables being prominent in period 1 are shown in the upper part of Figure 1C, and those being prominent for period 2 are placed on the lower part of Figure 1C. The differences between years were of minor importance (not shown), explaining only 15 % of the total variation, which also was confirmed by the ANOVA, showing the main effect of years to be non-significant.

The general impression of the apples after shelf-life was compared to the impression at the start of the experiment. After shelf-life, increase in shrinkage symptoms, greasier skin and a higher frequency of rot were observed. Generally, storage of apples in CA has been reported to maintain firmness better than storage in normal air (BEN-ARIE et al. 1993, GOFFINGS and HERREGODS 1994). The present experiments could not confirm these results, firmness showed a continuous decline, but only small and non-significant beneficial effects of CA-storage were found. Assessed after CA/NA-storage in December and after shelf-life trials in January, apples of the cultivar 'Summerred' were overripe and close to breakdown and had severe wilting

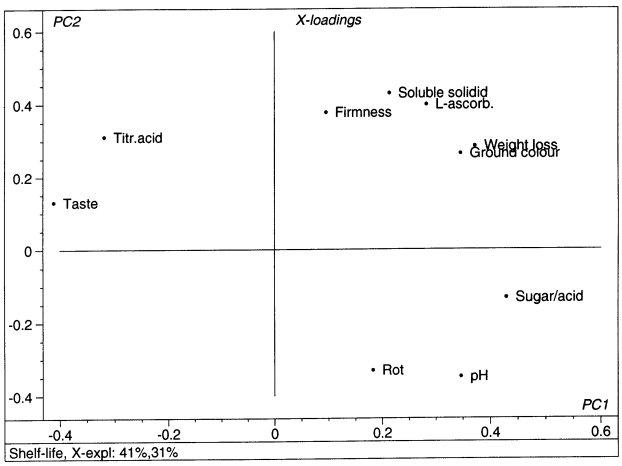



Fig. 1C. PCA-loadings for PC1 and PC2, showing the measured variables being related to years, storage period, and storage method,
*PCA-Ladungsplot der Principal Component Analyse für PC1 und PC2, zeigt die gemessenen Variablen der Versuchsjahre, Lagerungsperioden und Lagerungsmethoden.*

symptoms, and thus no longer acceptable eating quality.

The reduction in titratable acidity is important and should be taken into account in determining the optimum date for termination of storage (SEKSE 1992).

An important result with regard to nutritional value was the 15 mg L-ascorbic acid/100g fresh weight of 'Summerred'-apples found at harvest. At the end of the storage period, the content was reduced to about 10mg/100g, and after shelf-life trials the content was 10–12mg/100g. Compared to other reports on apples, these values are high (HULME 1970, CHRISTENSEN 1981). Recent measurements performed in Norway,

confirmed the high values of L-ascorbic acid in Norwegian grown 'Summerred' (HAFFNER et al. 1997). The concentrations of ascorbic acid in apples has been reported to be considerably higher grown at higher latitudes (Norway), compared to southern countries (Italy), (NILSSON 1967).

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## Literature

BEN-ARIE, R., A. LEVINE, L. SONEGO and Y. ZUTKHI 1993: Differential effects of $CO_2$ at low and high $O_2$ on the storage quality of two apple cultivars. Acta Horticulturae **326**, 165–174.

CHRISTENSEN, P. E., 1981: Æblesorter – C-vitamin. Frugt Avleren **10**, 276–282.

GOFFINGS, G. and M. HERREGODS 1994: The influence of the storage conditions on some quality parameters of 'Jonagold' apples. Acta Horticulturae **368**, 37–42.

HAFFNER, K., W. K. JEKSRUD and G. TENGESDAL 1997: L-ascorbic acid contents and other quality criteria in apples *Malus domestica* Borkh. after storage in cold store and controlled atmosphere. Proceedings of the Seventh International Controlled Atmosphere Research Conference – CA 97, University of California, Davis, July 13–18 1997, Postharvest Horticulture Series no. 16, oct. 1997, Vol. 2, Apples and pears, pp. 252–257.

HARDENBURG, R. E., A. E. WATADA and C. Y. WANG 1986: The commercial storage of fruits, vegetables and florist and nursery stocks. Agriculture Handbook Number 66 (revised), 130 pp.

HULME, A. C. 1970: The biochemistry of fruits and their products. Vol.1. Academic Press Inc. (London) Ltd., 629 pp.

HUSISTEIN, A. and U. GREMMINGER 1986: Neue Apfelsorten – Schnitt und Erziehung. Schweizerische Zeitschrift für Obst und Weinbau **122**(2) 36–44.

KVÅLE, A. 1969: Chemical composition of apples grown at different altitudes in the Sørfjord, Hardanger. Acta Agriculturae Scandinavica **19**, 3–10.

LANDFALD, R. 1980: Storing ability and fruit characteristics of the apple cultivars Aroma, Ingrid Marie, Lobo and Summerred. Frukt og Bær. Årsskrift for Frukt- og Bærdyrking 1980, pp. 60–69.

MEBERG, K. R., K. HAFFNER and H. J. ROSENFELD 2000: Storage and shelf-life of Norwegian grown apples: I. The effects of controlled atmosphere storage on 'Aroma'. Gartenbauwissenschaft **65** (1) 9–16.

NILSSON, F. 1967: Fruktkvalitet och klimat. Nordisk Jordbrugsforskning **49**, p. 274.

NORWEGIAN STANDARD (NORSK STANDARD), 1986: NS 2801, Norges Standariseringsforbund (NSF) 4. ed.

SEKSE, L. 1992: Changes in the content of soluble solids and titratable acids in apples during ripening and storage. Norwegian Journal of Agricultural Sciences **6**, 111–119.

SMITH, M.W.G. 1971: National apple register of the United Kingdom. SBN 855210176, 652 pp.

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