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'd' Anjou' Pear Fruit Quality as Influenced by Paper Wraps Infused with Inorganic and Organic Materials

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Abstract

'd'Anjou' pears wrapped in paper containing either 3, 6, or 9% oil with Copper & Ethoxyquin (Cu & E) or Biox A or E, packed after harvest and stored in regular atmosphere and controlled atmosphere storage, for periods not exceeding 120 days, maintained good quality. Storage of pears in paper containing diphenylamine (DPA) produced acceptable scores for appearance and finish, but some superficial scald occurred. Use of DPA, or DPA + Cu, in the paper wrap beyond 120 days of storage resulted in excessive damage in the form of scald. Quality of pears in wraps containing organic oils (lemon, clove, citronella) was approximately equivalent to use of dry paper and did not meet the quality of the industry standard wrap (3 % oil + Cu & E). If pears are to be held in long-term CA storage (210 days), only paper wraps containing 3 or 6 % oil + Cu & E should be considered. When packing pears, after loose storage in bins, the best quality fruit was obtained by wrapping the fruit in paper containing 3 % oil + Cu & E.

Introduction

For decades, 'd'Anjou' pears have been individually wrapped in paper impregnated with petroleum oils, fungicides, antioxidants and minerals to help control various disorders and reduce postharvest decay problems. Paper wraps have been used in the Washington State fruit industry since the early 1900s. Initially, paper wraps were used to cushion the fruit when in transit and to isolate decayed fruit. Use of oil-impregnated paper to reduce scald was suggested early in the 1900's (2). Cooley and Crenshaw (5) recommended that copper sulfate ($CuSO_4$) be incorporated in the paper wrap to prevent the spread of rot. Use of ethoxyquin or diphenylamine (DPA) to control fruit disorders, mainly scald, was suggested by Smock (12). Subsequent research (1, 3, 4, 7, 9,10) showed that either ethoxyquin or DPA effectively controls storage scald in tree fruits. Incorporation of ethoxyquin in paper wraps for scald control in pears has been proven to be effective (6, 11). Paper wraps impregnated with DPA have also been used in the fruit packing industry to reduce scald during storage. Recent consumer concern over the use of chemicals has generated interest in the incorporation of organic compounds in paper wraps to reduce storage disorders. This research was initiated to investigate the incorporation of organic compounds in paper wraps, their influence on fruit quality after storage and to compare these organic compounds with existing materials used in paper wraps.

Materials and Methods

This study was conducted over three crop seasons using commercially packed fruit. The commercial wraps used in this study were furnished by Wrap Pack, Yakima, WA. All wraps were manufactured one week prior to use to ensure freshness of the

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products impregnated in the paper. Pears were packed commercially at Blue Star Growers, Inc., Cashmere, WA or Underwood Fruit, Inc., White Salmon, WA. During the first year of the study, fruit were commercially packed shortly after harvest using paper wraps impregnated with one of the following groups of constituents: 1) 3% mineral oil + copper (Cu @ 1.3%) & ethoxyquin (E @ 1000 ppm), 2) 9% oil + Cu & E, 3) Biox-A @ 1000 ppm, 4) Biox-E @ 1000 ppm, or 5) diphenylamine (DPA @ 1000 ppm). Papers treated with 5.7% and 10.5% citric acid were tested in the first year only. After packing, fruit were placed in controlled atmosphere (CA) storage (1.5% O_2 & 1.0% CO_2 at 1°C) until evaluated, after 120 or 210 days of storage. In the second year, fruit was packed shortly after harvest using the same paper wrap treatments as in the first year except that the 9% oil + Cu & E paper was replaced by paper containing 6% oil + Cu & E and a paper incorporating 2.0% citric acid was included. The industry standard (3% oil + Cu & E) was used as a control during the entire study. Fruit quality was determined after 120 days of regular atmosphere (RA) storage and after 120 or 210 days of CA storage. In the final season, fruit was packed shortly after harvest using paper wraps impregnated as follows: 1) 3% oil + Cu & E, 2) lemon oil @ 3.0%, 3) clove oil @ 3.0%, 4) citronella oil @ 3.0%, or 5) a dry paper with no oil. Fruit quality was evaluated after 120 days of CA and 30 days of RA to simulate packing and shipping time. In addition, after 5 months of loose pack storage in CA, separate lots of fruit were removed and commercially packed using paper wraps impregnated with 1) 3% oil + Cu & E, 2) DPA only, or 3) DPA + Cu. Concentrations of Cu (@1.3%), E (@ 1000 ppm) and DPA (@ 1000 ppm) were held constant for all years of the study. Fruit quality was determined after wrapped pears were held an additional 30 or 60 days in RA storage. Four or more grower lots of fruit were used in each trial and grower lots were used as replications.

After each storage period, one box of pears of each paper type was removed and fruit quality evaluated. Fruit quality was evaluated using 20 pears immediately after removal from storage (same day) and on 20 pears after an additional 7 days of poststorage ripening at 20°C (estimate of shelf life). The remaining pears were ranked for rot and physiological disorders. Pears that were held in RA storage at 1°C (33/34°F) for an additional 30 days to simulate shipping and handling time were evaluated upon removal from RA and after 7 days ripening period as described. Quality factors determined were firmness, external and internal color, soluble solids concentration (SSC), titratable acidity (TA), general appearance, finish, stem condition, and scald.

Firmness was determined using the TA-XT2 Texture Analyzer (Texture Technologies, Scarsdale, NY) equipped with a 7.7 mm probe. External and internal color were determined with The Color Machine (Pacific Scientific, Silver Springs, MD) using the Hunter L*, a*, b* system and calculated hue values (4). SSC and TA were determined from a composite of juice expressed from longitudinal slices from each of 10 fruit. An Abbè type refractometer with a sucrose scale calibrated at 20°C (68°F) was used to determine SSC. TA was measured with a Radiometer titrator, model TTT85 (Radiometer, Copenhagen, Denmark). Acids were titrated to pH 8.2 with 0.1N NaOH and expressed as percent malic acid. After storage, one tray of 20 pears from each paper type was evaluated for general appearance, finish, shrivel and stem condition by 15 individuals skilled in quality control from five warehouses located in the Wenatchee area, using a scale of 1 = excellent, 2 = good, 3 = fair, and 4 = poor. Pears receiving scores between 2.5 and 3.0 were considered marginal in acceptability and those receiving scores 3.0 or greater were considered unacceptable. Superficial scald was evaluated by the same warehouses personnel and reported as the percent of scalded pears in a packed box. All data were analyzed as a completely randomized design with MSTAT-C (1988) using growers (4/5) as replications. Treatments were analyzed in a factorial arrangement using paper type as the main plot and storage time and ripening as the sub-plots. Means showing a significant F test were separated using Tukey's HSD test.

Results and Discussion

Paper wraps had no influence on objective fruit quality (firmness, color, SSC or TA) in this study (data not shown). In addition, none of the infused materials (3 or 9% oil + Cu & E, DPA, Biox-A, Biox-E, lemon oil, clove oil, or citronella oil) influenced objective fruit quality (data not shown). Effects in pear peel color due to paper type have been previously reported (6). Inclusion of 5.7% and 10.5% citric acid in paper wraps resulted in very poor quality pears (excessive scald and rot) after only a short storage period (data not shown); evaluation of 5.7% and 10.5% citric acid in the paper was terminated after a single season.

In contrast to the objective fruit quality measurements, subjective fruit quality assessments were strongly influenced by the products incorporated into the paper wraps. General appearance, finish and the amount of superficial scald present in pears packed shortly after harvest was strongly influenced by paper wraps (Table 1). After 120 days of CA storage, pears wrapped in paper with 3 % oil + Cu & E were superior in appearance and finish compared to pears in paper containing Biox E. Pears in paper with 9 % oil + Cu & E, DPA only or Biox-A were similar in appearance and finish and comparable to pears in paper with either 3 % oil + Cu & E or Biox-E. Pears in paper wraps containing DPA developed an excessive amount of scald. Scald was not a factor in pears wrapped in paper with 3 or 9 % oil + Cu & E, Biox-A or Biox-E, even though 4.0 % of the pears in paper with Biox-A displayed some scald. After 210 days of CA, only pears in paper with 3 or 9 % oil + Cu & E received acceptable scores (<2.5) for appearance and finish. Appearance and finish scores for pears in paper with DPA, Biox-A or Biox-E were all unacceptable (>2.5). After 210 days of CA, scald was controlled only by paper with 3 % oil + Cu & E but then not completely. The amount of scald in pears wrapped in paper containing either 9 % oil + C&E or Biox-E was similar but excessively high, while pears in paper with DPA or Biox-A developed an extreme amount of scald. In a previous study (6), there was no difference in the amount of scald present between pears in either 3 or 9 % oil + Cu & E. Chen et al. (3, 4) reported acceptable control of scald with the use of ethoxyquin (E) dips, but stated phytotoxicity could be a problem in long term storage. In this study, no phytotoxicity was evident with the use of E in paper wraps even after long-term CA storage (210 days).

Table 1. Influence of paper wraps on the general appearance, finish and scald of pear fruits after 120 or 210 days of controlled atmosphere storage (year 1).

	120 days storage			210 days of storage		
	Appearance	Finish	Scald	Appearance	Finish	Scald
Paper Wraps	(1 to 4)[z]	(1 to 4)[z]	(%)[y]	(1 to 4)[z]	(1 to 4)[z]	(%)[y]
3% oil + Cu & E	1.3b[w]	1.3b	<1b	1.9b	1.9b	10c
9% oil + Cu & E	1.7ab	1.5ab	<1b	2.4b	1.8b	37b
DPA	1.5ab	1.7ab	16a	3.4a	2.9a	72a
Biox-A	1.5ab	1.5ab	4b	3.3a	2.9a	67a
Biox-E	1.8a	1.8a	1b	3.4a	2.9a	53ab

[z] Evaluated on a scale of 1 to 4 (1 = excellent, 2 = good, 3 = fair, 4 = poor) N = 20.

[y] Total percent of scald in one box of fruit.

[w] Means in a column not followed by a common letter are significantly different by Tukey's (HSD) test ($P \leq 0.05$).

Table 2. Influence of paper wraps on the general appearance, finish and scald of pear fruits after 120 days regular atmosphere storage or 120 or 210 days of controlled atmosphere storage (year 2).

	120 days RA			120 days CA	210 days CA		
Paper	Appearance	Finish	Scald	Scald	Appearance	Finish	Scald
Wraps	(1 to 4)[z]	(1 to 4)[z]	(%)[y]	(%)[y]	(1 to 4)[z]	(1 to 4)[z]	(%)[y]
3% oil + Cu & E	2.4ab[w]	2.3ab	<1c	<1b	2.0b	2.1bc	<1b
6% oil + Cu & E	2.2bc	1.9b	<1c	<1b	2.6a	2.6a	<1b
DPA	1.8c	1.8b	5b	<1b	1.9b	1.9c	8b
2 % Citric	2.7a	2.7a	12a	11a	2.3ab	2.3ab	28a
Biox-A	2.1bc	2.1b	3b	2b	2.4a	1.6b	5b
Biox-E	2.4ab	2.3ab	5b	<1b	2.4a	1.7ab	7b

[z] Evaluated on a scale of 1 to 4 (1 = excellent, 2 = good, 3 = fair, 4 = poor) N = 15.
[y] Total percent of scald in one box of fruit.
[w] Means in a column not followed by a common letter are significantly different by Tukey's (HSD) test ($P \leq 0.05$).

In the second year of the study, after 120 days of RA storage, pears in paper with DPA received the best scores for appearance and finish compared to pears in paper with 3 and 6 % oil + Cu & E (Table 2). However, pears in DPA developed more scald than pears in paper containing 3 or 6 % oil + C&E, which showed very little scald after 120 days of RA storage. Pears in the wrap containing Biox-A or Biox-E were scored similar in appearance and finish to pears in paper with 3 or 6 % oil + Cu & E and similar to the amount of scald for pears in paper with DPA. Pears in paper containing 2 % citric acid were scored the worst for appearance and finish, and developed more scald than all other pears, regardless of paper type.

Appearance and finish scores after 120 days of CA storage were similar to the same scores for pears after 120 days of RA storage (data not shown). Very little scald was evident after 120 days of CA storage, except for pears in paper containing 2% citric acid. After 210 days in CA storage, pears in paper containing DPA received the best score for appearance and finish and were similar to the scores for pears in paper with 3 % oil +Cu & E. Pears in paper containing 6 % oil + Cu & E, Biox-A or Biox-E received the worst scores for appearance. The finish score for pears in paper with 6 % oil + Cu & E was unacceptable (>2.5), whereas the finish scores for pears in paper with either Biox-A or Biox-E were very acceptable (<2.0). Appearance and finish scores for pears in paper with 2 % citric acid were marginal (2.3), but not different than the pears in the other paper types except for DPA. The amount of scald present was similar in all paper types after 210 days of CA storage, except for 2 % citric acid, which showed significantly greater scald.

After 120 days in CA storage plus 30 days in RA (to simulate handling and transportation time), pears wrapped in paper with organic compounds (clove and citronella) compared favorably with pears wrapped in the industry standard of 3% oil + Cu & E, except for scald incidence (Table 3). Pears in paper with clove or citronella oil received scores for appearance and finish comparable to the scores received for pears in paper with 3% oil + Cu & E. Appearance scores for pears in either dry paper or paper with lemon oil were both unacceptable (>2.5), but the score for pears in paper with lemon oil was the only one scored significantly different to the scores for pears in the other papers. Finish scores for pears in dry paper or with

lemon oil were also unacceptable (>2.5). Finish scores for pears in both papers (dry or lemon) were considerably worse than the finish scores for pears in paper with citronella. Scald was present in all pears, regardless of paper type, but pears in dry paper developed considerably more scald than pears in paper with organic oils (lemon, clove, citronella). Pears wrapped in paper using the industry standard (3 % oil + Cu & E) developed much less scald than all other paper types. Good rot control was evident for pears in 3% oil + C&E, clove and citronella oil. Pears in dry paper developed some decay, but differences between papers were not present, except for pears in paper with lemon oil which developed considerable rot (5.0%).

Table 3. Influence of paper wraps on the general appearance, finish, scald and incidence of rot of pears after 120 days of controlled atmosphere storage followed by 30 days regular atmosphere storage (year 3).

Paper Wrap	Appearance (1 to 4)[z]	Finish (1 to 4)[z]	Scald (%)[y]	Rot (%)[y]
Dry (no Oil)	2.7ab[w]	2.6ab	40a	3.5ab
3 % oil + Cu & E	2.4b	2.3bc	4c	<1.0b
Lemon	2.9a	2.8a	24b	5.0a
Clove	2.4b	2.3bc	23b	<1.0b
Citronella	2.3b	2.1c	20b	<1.0b

[z]Evaluated on a scale of 1 to 4 (1 = excellent, 2 = good, 3 = fair, 4 = poor). N = 19.
[y]Total percent of scald or rot in one box of fruit.
[w]Means in a column not followed by a common letter are significantly different by Tukey's (HSD) test ($P \leq 0.05$).

At present there is industry-wide interest in storing pears loose in bins for later packing on demand. If pears have been stored loose for long periods of time and then wrapped in paper and packed, what would be the influence of the paper wrap on fruit quality? Objective quality (firmness, color, SSC, TA) of pears stored loose in bins and packed after 150 days of CA storage was not influenced by paper type (data not shown). However, subjective quality scores (appearance and finish) and the amount of scald present were influenced by paper type (Table 4). Appearance and finish scores for pears in paper wraps containing DPA compared favorably with the industry standard (3 % oil + Cu & E) after loose storage followed by packing. However, as was the case for pears wrapped and packed immediately after harvest, paper containing DPA did not provide acceptable control of scald. There was some scald present on pears in paper with 3 % oil + Cu & E, but the pears in paper containing either DPA alone or DPA + Cu developed significantly more scald. In this trial decay was not influenced by paper type.

Conclusions

Pears packed immediately after harvest and stored in RA and CA for periods of 120 days wrapped in paper containing either 3 to 9% oil + Cu & E, Biox-A or Biox-E maintained good quality. Use of paper containing DPA was possible with good scores for appearance and finish, but some scald development occurred. Use of DPA in the paper wrap beyond 120 days of storage resulted in excessive damage in the form of scald. Quality of pears in wraps containing organic oils is approximately equivalent to use of dry paper and did not maintain the quality of

the industry standard wrap (3% oil + Cu & E). If pears are to be held in long-term CA storage (210 days), only paper wraps containing 3 or 6% oil + Cu & E should be considered. When packing pears after loose storage in bins, the best quality fruit was wrapped in paper containing 3% oil + Cu & E. Fruit in paper containing DPA or DPA + Cu developed excessive amounts of scald.

Table 4. Pear quality after 150 days CA storage loose in bins followed by commercial packing using paper impregnated with either 3% oil + C&E, DPA only or DPA + Cu and storage for an additional 60 days in regular atmosphere conditions (year 3).

Paper Wrap	Appearance (1 to 4)[z]	Finish (1 to 4)[z]	Scald (%)[y]	Rot (%)[y]
3 % oil + Cu & E	2.2ab[w]	2.0a	9b	4.7a
DPA	2.4a	2.2a	17a	7.2a
DPA + Cu	2.0b	2.0a	16a	8.0a

[z]Evaluated on a scale of 1 to 4 (1 = excellent, 2 = good, 3 = fair, 4 = poor). N = 19.
[y]Total percent of scald or rot in one box of fruit.
[w]Means in a column not followed by a common letter are significantly different by Tukey's (HSD) test ($P \leq 0.05$).

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