

EFFECT OF DIFFERENT PAPER BAG TYPES ON APPLE FRUIT WEIGHT LOSS DURING STORAGE UNDER COLD AND WAREHOUSE CONDITIONS

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Abstract. This study investigates the influence of different fruit bagging materials on the post-harvest weight retention of apple (*Malus domestica* Borkh.) fruits. The experiment compared four treatments: Standard (control), White, Yellow, and Black paper bags under two distinct storage environments: uncontrolled warehouse storage and controlled cold chamber storage (0–2°C). Results indicated that storage conditions significantly impacted weight loss, with cold storage consistently preserving fruit mass better than warehouse conditions. Among the bagging treatments, Black paper bags resulted in the highest weight loss (12.7%) under warehouse conditions, likely due to thermal absorption and increased transpiration. Conversely, White paper bags demonstrated superior performance in warehouse storage (4.4% loss), outperforming the standard control. In cold storage, the Standard treatment exhibited the lowest weight loss (4.0%). These findings suggest that while cold storage is optimal, the selection of bagging material—specifically the avoidance of black bags and the use of white bags—is critical for preserving fruit quality in non-refrigerated supply chains.

Keywords: *Malus domestica*, post-harvest storage, fruit bagging, weight loss, cold storage.

Introduction. Apple (*Malus domestica* Borkh.) is one of the most widely cultivated and consumed fruits globally, valued for its nutritional content and storage potential. However, post-harvest losses remain a critical challenge for the apple industry, particularly in regions where cold chain infrastructure may be intermittent or unavailable. One of the primary indicators of post-harvest quality deterioration is weight loss, which is driven by transpiration (water loss) and respiration (carbon loss). Even a weight loss of 5–7% can result in visible shriveling, loss of turgor pressure, and a significant reduction in market value.

Fruit bagging is a technique widely adopted in modern horticulture, primarily applied during the pre-harvest stage to improve fruit coloration, reduce pesticide residues, and protect against mechanical damage and pests. While the pre-harvest benefits of bagging are well-documented, the impact of these bags on post-harvest storage performance—specifically regarding the residual effects of



the bag type on fruit physiology—is less explored. Different colored bags absorb and reflect solar radiation differently, potentially altering the histological structure of the fruit peel (cuticle thickness and lenticel density) during development, which subsequently affects post-harvest water retention.

This study aims to evaluate the effect of three different colored paper bags (White, Yellow, and Black) compared to a Standard control on the weight loss dynamics of apple fruits. Furthermore, it seeks to compare these effects under two storage regimes: ambient warehouse storage and controlled cold storage, to provide practical recommendations for post-harvest handling.

Materials and Methods. The experiment was conducted using apple fruits harvested at commercial maturity. The study utilized a randomized block design with four distinct treatments based on the bagging material used during fruit development: Standard: Control group (standard agricultural practice); White Paper Bags: Light-reflective bags; Yellow Paper Bags: Intermediate light-filtering bags; Black Paper Bags: Light-absorbing/opaque bags.

Post-harvest, the fruits from each treatment were divided into two groups and subjected to different storage environments for a set duration (data reflects final storage measurements): Warehouse Storage: Fruits were stored in a standard agricultural warehouse with ambient temperature and humidity fluctuations typical of the season; Cold Chamber Storage: Fruits were stored in a refrigerated chamber maintained at a temperature of 0–2°C and high relative humidity (85–90%) to minimize transpiration.

Results. The dynamics of fruit weight loss varied significantly depending on both the bagging treatment and the storage environment (Table 1).

Table 1. Effect of different paper bag types on apple fruit weight during storage

Variants	Warehouse storage			Cold chamber storage (0-2°C)		
	Initial fruit weight (g)	Final fruit weight (g)	Weight loss (%)	Initial fruit weight (g)	Final fruit weight (g)	Weight loss (%)
Standard	117,8	112,2	4,7	146,0	140,2	4,0
White paper bags	207,2	198,0	4,4	190,2	180,8	4,9



Yellow paper bags	205,4	191,6	6,7	184,8	171,4	7,2
Black paper bags	168,6	147,2	12,7	158,0	147,2	6,8

As expected, cold chamber storage (0–2°C) reduced weight loss across almost all treatments compared to warehouse storage. The most dramatic difference was observed in the Black bag treatment, where weight loss dropped from 12.7% in the warehouse to 6.8% in the cold chamber.

Under ambient warehouse conditions, the White paper bag treatment demonstrated the highest efficacy in preserving fruit weight, recording a loss of only 4.4%. This was superior to the Standard control (4.7%). The Yellow paper bags showed moderate performance with a 6.7% loss. The Black paper bags showed the poorest performance, with a substantial weight loss of 12.7%, nearly triple that of the White bags.

In the controlled cold environment, the Standard treatment performed best (4.0% loss), closely followed by White bags (4.9%). Interestingly, under these conditions, the Yellow bags exhibited the highest weight loss (7.2%), slightly higher than the Black bags (6.8%).

It is also noteworthy that bagging treatments appeared to influence initial fruit size. Fruits from the White and Yellow bag treatments were significantly heavier (207.2 g and 205.4 g in warehouse groups) compared to the Standard control (117.8 g). This suggests a positive pre-harvest impact of bagging on fruit biomass accumulation.

Discussion. The results highlight the critical interaction between pre-harvest bagging materials and post-harvest environmental conditions.

Thermal Effects and Transpiration. The poor performance of Black paper bags in warehouse storage (12.7% loss) can be attributed to the thermal properties of the color black. Black surfaces absorb a broad spectrum of solar radiation, likely raising the temperature of the fruit during the pre-harvest stage or, if the bags remained on or near the fruit during handling, continuing to absorb ambient heat. Higher fruit pulp temperature accelerates respiration and transpiration rates, leading to rapid moisture loss. However, when these fruits were placed in a Cold Chamber (0–2°C), the low temperature effectively mitigated this thermal disadvantage, reducing the loss to 6.8%. This underscores that black bags are particularly risky for supply chains lacking robust refrigeration.



Reflectivity and Cuticle Integrity. The superior performance of White paper bags in warehouse storage (4.4% loss) supports the hypothesis that lighter-colored bags reflect excess heat and light. This likely prevents heat stress during fruit development, allowing for the formation of a healthy, intact wax cuticle. A well-formed cuticle serves as the primary barrier against water loss. The fact that White bags outperformed the Standard control in ambient conditions suggests they offer a protective advantage that extends into the storage period.

Fruit Size and Surface Area. Generally, larger fruits (such as those in the White and Yellow groups) have a smaller surface-area-to-volume ratio compared to smaller fruits (Standard group), which theoretically should result in slower percentage weight loss. However, the Yellow bags showed higher losses (6.7–7.2%) despite having large fruit sizes. This implies that the yellow bag material may have induced specific physiological changes—such as increased lenticel porosity or a thinner cuticle—that made the fruit more susceptible to desiccation regardless of its size.

Conclusion. This study concludes that while cold storage at 0–2°C is the most effective method for minimizing weight loss in apples, the choice of bagging material plays a significant role, particularly in the absence of refrigeration. White paper bags are the most effective treatment for preserving fruit weight under ambient warehouse conditions, likely due to their thermal reflective properties. Black paper bags are highly detrimental to storage quality in warehouse conditions, causing excessive weight loss (12.7%), and should be avoided unless immediate cold storage is guaranteed. Cold storage effectively standardizes the performance of different treatments, though the Standard and White bag treatments remain the most efficient for weight retention.

