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Review on the Role of Different Packaging Materials on Post Harvest Shelf Life and Quality Preservation of Banana (*Musa spp*) Fruits

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Abstract

Banana (Musa spp L.), is one of the most important fruit crop of the world and it belonging to the family Musaceae. Banana is a very popular fruit due to its low price and high nutritive value. It is a rich source of Carbohydrate and is rich in vitamins particularly vitamin B. Its production is also an important source of income for many small holder sub-Saharan African farmers. It has a great socio economic importance, contributing much to the overall well-being of rural communities including food security, income generation and job creation. The post-harvest losses of fresh banana fruits go up to 30-40% globally. The losses occur on account of various factors such as lack of storage facilities, improper handling, and lack of packaging and refrigerated storage facilities. This invariability led to quantitative and qualitative loses. Significant proportion of banana fruits has been lost in Ethiopia due to lack of awareness on effect of packaging materials on shelf life and quality of harvested banana fruit. Similarly, lack of postharvest and marketing infrastructures such as packaging, cold storage, pre-package and distribution, postharvest treatment and washing facilities together with production constraints are reported problems leading to low productivity and considerable postharvest loss of banana in Ethiopia. The potential for solving some of the problems related to banana shelf life and quality and its postharvest maintenance is through the use of different packaging materials. The main objective of this seminar paper is to review the Effect of Different Packaging Material on Shelf Life and Quality of Banana (Musa spp) Fruits.

Keywords: Banana, Postharvest Factors, Quality and Shelf Life

1. Introduction

Banana (Musa spp L.) belonging to the family Musaceae, is one of the most important fruit crop of the world. It is a tropical, herbaceous, monocotyledonous and monocarpic fruit crop [1]. Banana is a large perennial herb with leaf sheaths that form the trunk like pseudo stem. They vary in height from 1.5-8 m and generally divide in to starchy type called plantation and the desert type known as banana [2]. It is the second largest produced fruit and eighth most important food crop in the world [3,4].

Banana is a very popular fruit due to its low price and high nutritive value. It is consumed both in fresh and cooked form both as ripe and raw fruit, is a rich source of Carbohydrate and is rich in vitamins particularly vitamin B [5]. Economically banana is a very popular fruit due to its low price and high nutritive value [6]. It's production is also an important source of income for many small holder sub-Saharan African farmers [7] .Especially in the south and south western parts of the country, it is of great socio economic importance, contributing much to the overall well-being of rural communities including food security, income generation and job creation. According to Uma et al. (2008), banana helps in reducing the risk of heart diseases when used regularly and is recommended for patients suffering from high blood pressure, ulcer and kidney disorder [6].

Ethiopia is among the tropical countries where its vast arable land is suitable for banana cultivation. Banana ranks first among fruit crops in area coverage (67,387 ha) and production (539,443 t) [7]. The national average yield of banana is estimated at 8.0 t ha-1, which is far less than the world average (22.6 t ha-1) [7]. The low productivity of banana is mainly attributed to limited provision of production technologies such as improved varieties and crop management practices, diseases and insect pests, poor postharvest handling and marketing, and insufficient support from the extension system [8,9].

The post-harvest losses of fresh banana fruits go up to 30-40% due to improper handling, storage and other reasons like browning, abrasion, senescence, skin discoloration, fungal decay etc [10]. Banana is a very perishable fruits and it possesses very short shelf life nearly 10-12 days under ambient condition; both ripe and unripe banana is very susceptible to mechanical damage [1]. In Ethiopia there is no proper means of postharvest handling of fruits and vegetables at the retail and wholesale levels, which results in poor quality of banana at the consumer level. Although the country is experiencing huge postharvest losses of banana very little or no emphasis is given to postharvest handling of the fruit [11]. The losses occur on account of various factors such as lack of storage facilities, improper handling, and lack of packaging and refrigerated storage facilities. This invariability leds to quantitative and qualitative lose [12].

The spoilage of banana is mainly due to harvesting at improper stage of maturity. Physical damage during transport, consequent fungal infections, and fungal breakdown primarily leads the fruit to senescence. Packaging of the fruit protects from physical damages and contaminations at retail level [13]. Generally, significant proportion of banana fruits has been lost in Ethiopia due to lack of awareness on effect of packaging materials on shelf life and quality of harvested banana fruit. Therefore, this loss can be kept minimum by improving postharvest handling techniques through the use of different locally available packaging materials. Hence, it is necessary to understand the effect of different packaging using different local materials on quality and shelf life of banana.

2. Literature Review

2.1. Concepts of Post-Harvest Loss

The term "postharvest loss" - PHL refers to measurable quantitative and qualitative food loss in the postharvest system . Quantity losses refer to those that result in the loss of the amount of a product. Loss of quantity is more common in developing countries [14]. Quality losses include those that affect the nutrient/caloric composition, the acceptability, and the edibility of a given product. These losses are generally more common in developed countries.

2.2. Extent of Post-Harvest Losses of Banana Fruits

Banana is the most important fruit crop representing about 40% share by weight in world trade of fruits, either fresh or processed. India is the largest producer of banana, with an annual production of 7.9 million MT. Shelf life of fully matured banana under tropical conditions is limited to a short period. During peak season, due to a large volume of fruits available, the producers are faced with low returns due to perishable nature of the commodity [15]. Banana is a highly perishable fruit and its quality is reduced and considerable amount is wasted, from harvesting to final consumption during transporting and marketing due to adverse physiological changes, softening of the flesh, and lack of resistance capacity against microbial attack [16]. Post-harvest loss of banana in Ethiopia were carried out earlier on certain localities and losses ranging from 26.5% to 30-40% were reported at various levels of handling.

The global share of Ethiopia in banana export was only 0.02% in 2011 which could be described partly to problems associated with post-harvest handling to meet quality standards of the export market [17]. A study conducted among producers, wholesalers and retailers of fruits in the fruit market chain revealed that, Losses of horticultural produce are a major problem in the post-harvest chain [18]. The study that was conducted in Ethiopia since 2015 revealed that, the average total farm level loss of banana was 15.6% of the total production due to improper transport and storage. The total post-harvest loss of banana at wholesalers and retail level were found to be 29.25% .The higher proportions of losses (64.10%) were observed at retailer's level while the 35.90% losses were found at wholesalers level [19]. The high percentage loss at the retailers could be accounted for the cumulative effect of improper handling from harvest to retailers' level and inappropriate display conditions and handling facilities [20]. The perishable nature of ripe fruits also makes the problem worse at the retailers' level. The relatively lower magnitude of loss at whole salers' level could be explained by the fact that whole-salers are mostly dealing with green fruits. Though the damage is prevalent later at ripening, green fruits are more tolerant to handling problems [19].

Supply chain	Loss (%)	Share in total (%)
Wholesale level	10.5	35.90
Retail level	18.75	64.10
Total	29.25	100
Source: Etana *et al*., (2021) [19].		

Table 1: Post-Harvest Losses of Banana at Wholesalers and Retail Level

2.3. Causes of Post-Harvest Losses of Banana Fruits

Generally, the primary factors causing postharvest loss in fruits can be categorized in to mechanical, physiological, pathological or environmental factors. The losses are favored by secondary factors resulting mainly from inadequate technology applications and quality control. A high postharvest loss caused by inadequate and inefficient postharvest handling practices, is reported to be one of the major problems limiting the expansion of banana production in Africa. Similarly, lack of postharvest and marketing infrastructures such as packaging, cold storage, pre-package and distribution, postharvest treatment and washing facilities together with production constraints are reported problems leading to low productivity and considerable postharvest loss of banana in Ethiopia [15].

2.3.1. Causes of Post-Harvest Losses of Banana at Wholesaler Level

According to response of wholesalers (28.15%), mechanical damage was the main cause for banana losses at wholesalers level, improper transport, improper storage, improper ripening and improper maturity which were noted by the remaining 22.71%, 19.46%, 17.26% and 12.42% of the respondents, respectively .The processes of fruit handling and packing from harvest through transport and marketing might contribute for mechanical damage to banana at whole sale market. Poor handling, unsuitable containers, improper packaging and transportation are indicated to easily cause bruising, cutting, breaking, impact wounding and other forms of injury leading to fruit deterioration [14]. Long distance transport followed by poor packaging during transport and improper storage also had their own contribution for loss of banana fruit .Transporting banana bunches without cushioning material may expose fruits to mechanical damage which resulting in losses [21].

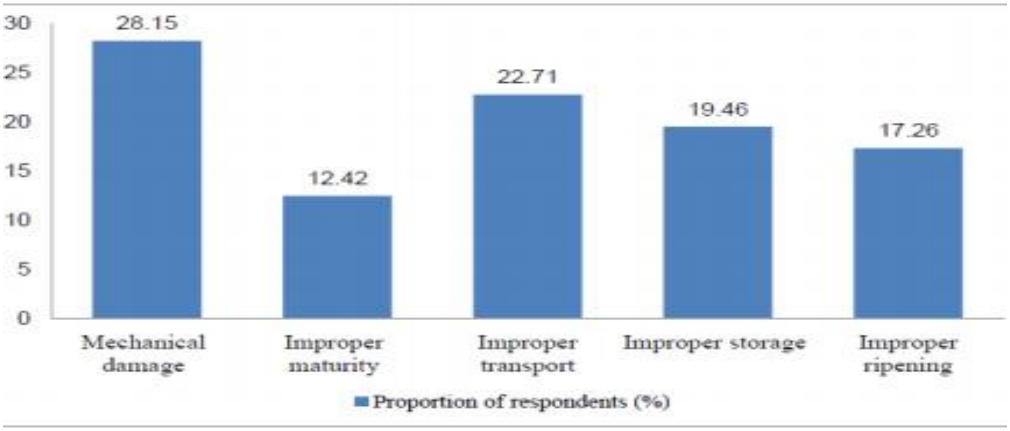

Figure 1: Causes of Post-Harvest Loses of Banana at Whole-Salers Level
Source: Getachew Etana *et al*., (2021).

2.3.2. Causes of Post-Harvest Losses of Banana at Retail Level

Fruit ripening was mentioned by majority of the retailers (36.75%) as the main cause for banana fruit loss while improper ripening, mechanical damage, improper transport and improper maturity were noted by 28.26%, 15.89%, 10.32% and 8.78% of the retailers, respectively . The possible reason to score high in rotting could be explained by the fact that during handling, fruits are infected with various pathogens which can be established at any time before or after harvest which resulted to cause decay in fruits. Banana pathogens gain entry through injuries happened during harvesting and injuries related to poor handling and transport. During storage, banana fruit deteriorates through the action of spoilage microorganisms, which become activated due to the changing physiological and biochemical state of the fruit [22]. Improper ripening in banana fruit also leads to an increased susceptibility to physical damage and pathogen attack during storage which increases the risk of fruit spoilage at retail market. Microbial and mechanical damage also interact with the changing physiology of the fruit during ripening and storage will result in great fruit losses [22].

The impact of mechanical damage might be increased at retail level because injuries from the previous handling chains will be more prevalent on the ripe banana fruit. The physiological state of the fruit (ripening) by itself also makes the fruit more sensitive to handling damages [23].

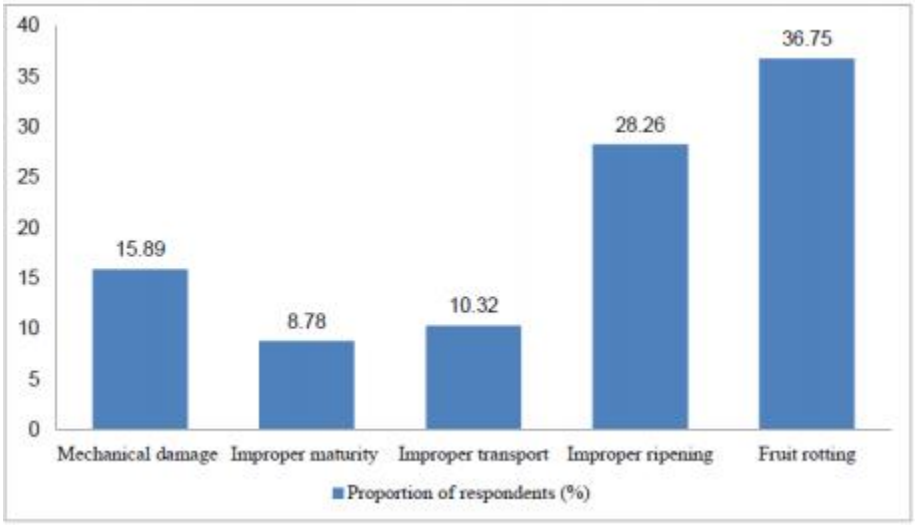

Figure 2: Causes of Post-Harvest Loses of Banana at Retail Level
Source: Getachew Etana *et al*., (2021)

2.4. Effect of Different Packaging Materials on Post-Harvest Loses of Banana

The quality of banana is reduced and considerable amount is wasted, from harvesting to final consumption. This loss can be kept at minimum by improving postharvest handling techniques through the use of packaging materials or through improving traditional packaging practices [24]. In most of the time the traditional packaging method for banana is best packaging in which dried banana leaf and straw of teff are used but the effectiveness of these packaging materials even has not yet been investigated. Modified atmospheric packaging (MAP) has also been found to increase the shelf life of banana fruit. It is often desirable to generate an atmosphere low in O2 and/or high in CO2 to influence the metabolism of banana being packaged or the activity of decay-causing organisms to increase storability and/or shelf life [25]. In addition to atmosphere modification, MAP vastly improves moisture retention. Furthermore, packaging isolates the product from the external environment and helps to ensure conditions [26].

2.4.1. Effect of Different Packaging Materials on Physiological Weight Loss of Banana Fruits

Weight loss of fresh fruits is primarily due to transpiration and respiration [27]. Transpiration is a mechanism in which water is lost due to differences in vapor pressure of water in the atmosphere and the transpiring surface [28]. Respiration causes a weight reduction because a carbon atom is lost from the fruit, each time a carbon-dioxide molecule is produced from an absorbed oxygen molecule and evolved into atmosphere [23]. Higher respiration rate also resulted in higher transpiration of water from the fruit surface which led to increase in percentage of weight loss [29]. The result obtained from Zerga and Tsegaye (2020) revealed that the highest physiological weight loss (21.74) was recorded at the control (unpackaged) followed by banana leaf (15.59) whereas the lowest weight loss (6.56) was recorded from polyethylene bag.

Treatments	**Weight loss(g)**				**Over all mean**
	Day4	Day8	Day12	Day16	
Polyethylene bag	0.52	3.13	8.26	14.18	6.56^{d}
Carton box	1.82	5.74	11.18	27.75	11.55^{c}
Banana leaf	3.10	7.06	14.13	38.08	15.59^{b}
Teff straw	2.32	5.59	14.12	33.42	14.11^{bc}
Control	6.19	12.94	17.92	50.72	21.74^{a}
LSD					3.12
CV(%)	6.78	9.87	5.89	10.76	9.85
Source: (Zerga and Tsegaye, 2020) [20]					

Table 2: Mean Comparison for Physiological Weight Loss and Color of Banana Fruit as Influenced by Packaging Material

2.4.2. Effect of Different Packaging Materials on Shelf Life of Banana Fruits

Shelf life is the period from harvesting up to the last edible stage [30]. The shelf life of a product depends on initial quality of the food products, amount of quality change that can be allowed, prevailing environmental condition, and brakes properties of the packaging materials, and compatibility between food product and packaging [31]. Packaging exhibited great role in extending the shelf life and minimizing the wastage by inhibiting undesirable physiological events, bruising and pathological deterioration during storage, transportation and marketing. Packaging materials also influenced PLW, TSS, firmness, respiration rate and total sugars of pomegranate and polypropylene bags maintained better quality [8]. The suitable packaging materials provides congenial environment which reduces the ethylene production, undesirable biochemical changes, ripening, slows down the rate of respiration, desiccation and pathological deterioration of fruits [15]. Polyethylene bags are used extensively to prolong shipment and storage life of banana and other fruits as they retard respiration and transpiration and retain quality of fruits. There are several loss reduction technologies devised to minimize the post-harvest deterioration and extension of shelf life of banana [6]. The efficiency of different packaging and cushioning materials varies from fruit to fruit. Therefore, selection of suitable packaging material is of primary importance to understand post-harvest behavior of banana fruits as affected by different post-harvest treatments to alleviate the post-harvest losses, extend shelf life, maintain quality and ensure safety of fruits [32].

According to Esa Abiso et al.(2018) the banana fruit treated by clove with cartoon (CC) and ginger by cartoon (GC) showed the longest shelf life (8 days) followed by HC and CN (6 days) [13]. The lowest shelf life had been recorded on HJ and CO (4 days)

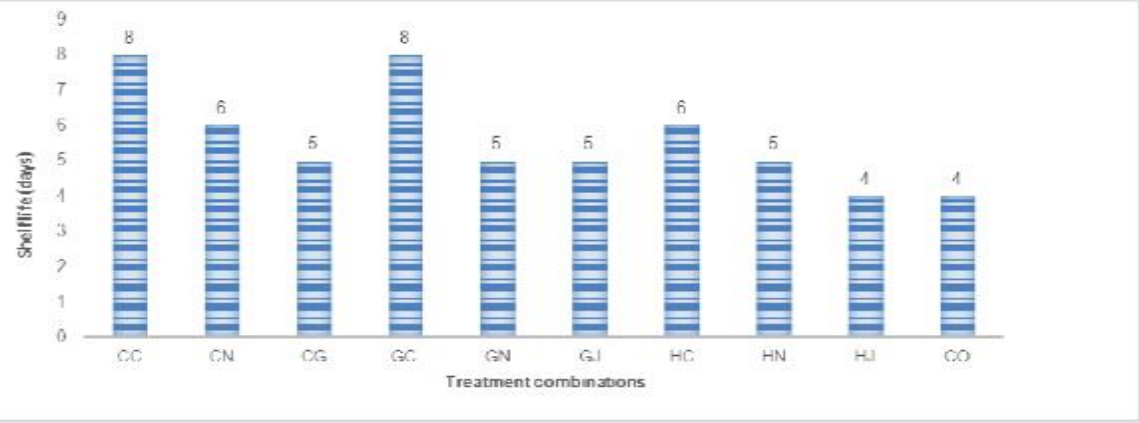

Figure 3: Shelf Life of Bananas Stored Under Different Packaging Materials and Postharvest Treatment
Source: Esa Abiso *et al*. (2018) [13].

2.4.3. Effect of Different Packaging Materials on Decay Percentage of Banana Fruit

The main cause for fruit deterioration is fruit ripening and ethylene production. High temperature fastens the rate of fruit ripening, thus fastens the rate of fruit deterioration. The evaporative coolers reduce the inside storage temperature which slows the rate of fruit ripening and ethylene production. These have a direct effect on shelf life extension of the fruit [31]. The deterioration of banana fruit was recorded mostly during harvesting followed by marketing, transporting, storage, and in some causes through the entire channel. This is because fresh produce after harvest continues the process of respiration and transpiration until its reserved food and water are reserved [33]. This physiological process is influenced by temperature, composition of surrounding air, and humidity of the environment.

According to Esa Abiso et al.(2018) the highest decay % was found in bananas stored at ambient on the 4 th storage day (100%) and the lowest decay % was observed in bananas which were treated by CN (10%) [13]. On the 8th days of storage on most storages the fruit was 100% deteriorated but storages like CJ and CN still performs to the best (only15% deterioration). Generally, combination of the packaging and postharvest treatment together perform better than the ambient storage condition.

Treatment combination	Decay percentage (%)	
	Day 4	Day 8
Ginger x carton	70.00(0.0078)b	100(0.0157)a
Ginger x Jut sack	70.00(0.0078)b	100(0.0157)a
Ginger x Newspaper	13.33(0.0013)de	33.33(0.0033)cd

Clove x Carton	36.66(0.0037)c	70.00(0.0078)a
Clove x Jut sack	13.33(0.00130de	15.00(0.0015)de
Clove x Newspaper	10.00(0.0010)de	40.00(0.0041)c
Hot water x Carton	13.33(0.00130de	23.33(0.0023)cde
Hot water x Jut sack	26.66(0.0026)cd	40.00(0.0041)c
Hot water x newspaper	13.33(0.00130de	15.00(0.0015)de
Control	100(0.0157)a	100(0.0157)a
LSD (5%)	0.0015	0.0018
CV (%)	9.58	8.86
Source: Esa Abiso *et al*. (2018)		

Table 3: Decay Percentage of Banana Stored Under Different Packaging Material and Postharvest Treatments for 8 Days

2.4.4. Effect of Different Packaging Materials on PH of Banana Fruits

According to Zerga and Tsegaye (2020) the highest pH value was recorded for bananas packed by banana leaf and teff straw whereas the lowest pH was observed in the control treatment followed by banana treated by carton box and polyethylene bag [24]. In general, pH of the banana fruit increased with the advancement of fruit ripening. Since acidity of the fruits is due to various organic acids that are consumed during respiration [34]. The acidity thus decreased with advancing maturity or increasing storage duration with a corresponding increase in fruit pH [35]. Amino acid has also been showed to be the main acid in banana juice, with pH of fruit normally between 6.2 and 6.7 [12].

Treatments	**PH**			**Overall mean**	**TSS**			**Over all mean**
	Day8	Day12	Day16		Day8	Day12	Day16	
Polyethylene bag	4.167	5.096	4.47	4.65ab	20.41	22.41	21.27	21.36a
Carton box	4.40	5.123	4.18	4.56ab	17.17	18.40	16.98	17.52bc
Banana leaf	4.883	5.81	4.753	5.15a	4.48	17.27	15.96	15.91cd
Teff straw	4.567	4.986	4.50	4.70a	9.31	21.53	20.23	20.36ab
Control	4.18	4.213	3.856	4.07a	5.35	14.47	11.47	13.88d
LSD				5.76				16.3
CV (%)				5.99				7.44
Source: (Zerga and Tsegaye, 2020)								

Table 4: PH of Banana Stored Under Different Packaging Material

2.4.5. Effect of Different Packaging Materials on Percentage of Marketability of Banana Fruits

According to Mebratu and Muneda (2019) the percentage marketability of banana fruit was significantly affected by the packaging materials [5]. After 8 days, all the control fruits became unmarketable whereas fruit packaged in plastic bag (T3) and dried banana leave (T2) continued until day 12.Since fruits were exposed directly to the atmosphere, control fruits had lost more weight than banana leaf and teff straw. In the study, the main causes of marketability of control fruits was color change and weight loss. Even though fruits packaged in plastic bag and dried banana leave were found to be better than control fruits in preventing the weight loss, they became unmarketable totally due to weight loss. But fruits packaged in polyethylene bags continued being marketable until date 15.

Treatments	**Day0**	**Day4**	**Day8**	**Day12**	**Day15**
Teff straw	-1	100^{a}	100^{a}	100^{a}	100^{a}
Dried banana leave	-	100^{a}	100^{a}	100^{a}	100^{a}
Plastic bag	-	100^{a}	93.1^{b}	83.2^{b}	72.6^{b}
Control	-	94.8^{b}	84.9^{c}	68.6^{c}	55.2^{c}

CV	0.00	1.00	1.34	2.07	1.84
Source; (Mebratu and Muneda, 2019)					

Table 5: Effect of Packaging Material on Percent Marketability

3. Conclusion and Future Line of Work

Conclusion

Banana is a highly perishable fruit with global post-harvest losses of 30-40% and approximately 29.25% in Ethiopia, where retail-level losses reach 64.10%. Major causes include mechanical damage, improper transport and storage, and poor ripening practices [36,37]. Packaging materials significantly influence banana shelf life and quality. Polyethylene bags are most effective, reducing physiological weight loss to 6.56% (versus 21.74% in unpackaged fruit), extending shelf life to 15 days, and maintaining 72.6% marketability. Traditional materials like banana leaves and teff straw offer moderate benefits but are less effective than polyethylene.

Polyethylene bags create modified atmosphere conditions that reduce respiration rates, ethylene production, and transpiration, thereby slowing ripening. Combining packaging with postharvest treatments (e.g., clove or ginger extracts) further reduces decay and enhances shelf life. Proper cushioning and packaging throughout the supply chain are essential to minimize mechanical damage and associated losses.

Future Line of Work

Based on the findings of this review, the following recommendations are proposed:

- Evaluate the effectiveness of combining different packaging materials with eco-friendly postharvest treatments (botanical extracts, hot water treatment)
- Develop affordable, biodegradable packaging alternatives that provide similar benefits to polyethylene bags while addressing environmental concerns
- Investigate the optimal perforation density in polyethylene bags to balance modified atmosphere conditions with prevention of anaerobic respiration
- Comprehensive cost-benefit analysis of different packaging materials should be conducted to guide adoption decisions by smallholder farmers and traders, considering local availability, affordability, and environmental sustainability of packaging options.

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