Effect of Nanocomposite-based Packaging on Postharvest Quality of Water Content-treated Coffee Beans during Storage

Erdawati, Riskiono
Dept of chemistry, State University of Jakarta

Abstract

The objective of this study was to evaluate the physical, chemical, and sensory qualities of green coffeebeans (Coffea arabica L.) during storage in nanopackaging packaging. A novel nanocomposite-based packaging (NCP) was prepared by blending polyethylene (PE) with nano-Ag,chitosan nanoparticle and montmorillonite. The effects of NCP on the quality parameters of water content tretaed coffee beans were investigated during the 21 d of storage at 25 °C. The results showed that adding nanoparticles to the PE significantly decreased the oxygen, water vapor permeability and longitudinal strength . The weight loss, water content , color variation and proximate content of coffee bean were significantly inhibited by 22.67%, 124.84%, 23.46% and 14.42% The results of this analysis demonstrated that this NCP can potentially increase the effectiveness of methods used to preserve and maintain quality in coffe beans during postharvest storage.

key word : NCP, coffe bean, water content

1. Introduction

Coffee is one of the most widely consumed beverages in the world because it contains a wide range of aroma compounds, which is a very important factor in food quality [1].Coffee beans are obtained from the plants Coffea arabica and Coffea canephora (mainly variety robusta). The former is more valuable because its beans produce a better tasting beverage, which is therefore more expensive than the robusta coffee [2] .

Coffee is an agricultural product with a quality-based price. The value of coffee increases significantly with improvements in quality, which are necessary to obtain new markets. During roasting,the taste and aroma of coffee develop from ingredients originall present in raw beans. Taste and aroma are the principal factors affecting beverage quality Storage is one of the stages following production that strongly influences the commercialization of coffee beans. Storage is therefore considered one of the most important factors for maintaining final product quality, meeting between-harvest demand, and securing the best market price for the producer.

Traditionally, green coffee beans have been stored in jute sacks.Jute is most frequently used because it is readily adaptable to smallscale commerce and because it is easily sampled for lot inspections. Elevated operational costs that result from the need for manual handling represent one disadvantage of storage in jute sacks..Another disadvantage is rapid deterioration in quality when the beans are stored in warehouses without ambient air control. Containers called "big bags" represent another form of storage used in Brazilian warehouses. The ease of mechanized handling, along with operational economies of scale, represent the principal advantages offered by this method of storage. However, big bags, like jute sacks, have the disadvantage of being permeable to water vapor and to gases present in ambient air, affecting the color and the organoleptic properties of the beans[3], and Nobre et al. [4] have stated that storage in hermetically sealed systems that permit atmospheric modification or control represents a viable alternative for preserving coffee bean quality. Certain additional costs are acceptable for the preservation of quality in select coffees of higher value.

Recently, the application of the nanocomposite concept has been proven to be a promising option in order to improve above mentioned properties conveniently [5] It is worth emphasizing many diverse characteristics existed in nanocomposites including composite reinforcement, barrier properties, flame resistance, electro-optical properties, cosmetic applications and bactericidal properties.

Relatively little research has been conducted to the food packaging involving in nanotechnology, such as material development of biodegradable starch/clay [6] whey protein isolate/ clay[7] polylactides/nanoclay composite films [8] and their application in Chinese jujube [9] green asparagus [10], orange juice [11] and Chinese bayberries [12]. Microbial growth rate inorange juice were significantly reduced as a result of using packaging material containing Ag and ZnO nanoparticles, which prolonged the shelf life of fresh orange juice up to 28 days without any negative effects on sensorial parameters [11]. Our previous study also showed that the nano-packing had quite beneficial effect on sensory, physicochemical, and physiological quality of fresh strawberry than polyethylene bags [13] .To the best of our knowledge, there are no published reports on the effect of nanocomposite-based packaging on preservation of kiwifruit. Therefore, the objective of the present work was to develop a preferable nanocomposite-based packaging to preserve coffee bean and to investigate the effect of NCP on maturity of coffe bean induced by watwr vapour during cold storage. To well understand the effect of this novel nanocomposite-based packaging material, the morphological characterization, physical properties and antibacterial effect of the nanocomposite were conducted as well.

Better understanding of storage factors and the advent of new forms of packaging permit extension of coffee storage times. These developments are of immense importance for preserving product quality. Preservation of product quality over longer periods of storage secures a longer sales period for growers and guarantees better prices. To achieve these goals, the present study proposes and evaluates a new storage system that preserves the physical, chemical, and sensory qualities of stored green coffee beans on a commercial scale using nanopackaging.To reduce these effects of microbiological, chemical and physical events, it is possible to act on food processing or, more usually, on packaging. However, toughness and other properties such as thermal stability, medium gas barrier, low solvent resistance (e.g., against water) and antibacterial properties of pure polymer are often insufficient for food packing applications [14]

2. Materials and methods

material The low-density polyethylene (PE) was used as matrix material (Translucency, Melt flow index 2.2 g/10 min, density 0.92 kg/m3, softening point 95 °C, A. The nanopowders (35 wt.% of nano-silver, 40 wt.% of nanoparticle chitosan and 25 wt.% of Na^+ montmorillonite) in the range of 40–80 nm were obtained from a analytical chemistry laboratory, state universiti of Jakarta.

2.1. Preparation and characterization of nanocomposite based packaging

Firstly a PE-nanocomposite masterbatch containing 30 wt.% of the nano-powder, 56 wt.% of PE granule and 14 wt.% of cross-link reagent KH-570 were immingled in uniformity through a high-speed mixer for 1 h. After air cooling, they were extruded to PE nanocomposite masterbatch using a twin-screw extruder with a screw diameter of 22 mm, a screw length/diameter ratio of 42 and a screw speed of 600 rpm.

In the second extrusion step, 0.15 kg of masterbatch and 3.85 kg of PE granule were immingled for 30 min. Subsequently the compounds were blown into a film of 50 μm thickness via a plastic extruder After cooling, films of 50 μm thickness were used to make bags of 20×22 cm2 using a heat sealer (Polyethylene bags of the same thickness and size without nanocomposite masterbatch nano-powder served as controls.

2.2 Surface area analysis

The specific surface area and average pore size of the nanopackaging film were determined by nitrogen adsorption at 77 K (Quantachrome Autosorb 1).The nanopackaging film were outgassed at 300 °C for 12 h and 150 °C for 8 h, respectively. The BET method was used for the corresponding calculation.

2.3. Physical properties analysis of NCP

Measurements of the water vapor permeability (WVP), oxygen permeability (OP) and longitudinal strength were carried out by thesheet-cup method, differential-pressure method and mechanical determination respectively according to National Standard of Indonesia(SNI . The test film was sealed to a permeation cell with a 50% relative humidity gradient across the film at 23 °C. Five measurements were performed for each sample.

2.4. Plant material

The experiment was conducted in a warehouse of the Coffe Society PT in Sukmajaya Bogor, Eas Java, Indonesia. The coffee used in the experiment was obtained from a lot taken from the 2008 (Coffea arabica L.) crop and passed through 17 and 18 screens. The beverage made from this lot had a minimum score of 80 points, classifying it as good-quality coffeeon the Specialty Coffee Association of America (SCAA) scale. Coffee was bagged in 1 kg quantities in nanopackaging pastic sack and LDPE plastic.

2.5. Treatment

The coffee samples were randomly collected using a grain sampler in the nanopackaging For all package, 500 g of coffee beans were collected at 3-months intervals at 0, 1, 2, 3 and 4 months of storage. The samples were analyzed to determine water content, color, and content of sugars. Sensory analysis was also performed at these sampling times. The analyses were performed at the Laboratory of Agricultural Products, Department of Food and Technology, Institute of Agiculture Bogor. All analyses were made using bean samples passed through 17 and 18 screens to guarantee uniformity during roasting.

2. 6. water content

Water content was determined by oven-heating at 105^0C for 16 h. Bean color was determined on a Minolta model CR300 colorimeter by direct reading of the coordinates (L), (a), (b) and according to the method described by Nobre (2005).

2.7. Color measurement

Color was measured using a digital imaging method that used a combination of a digital camera (Panasonic, Japan), a computer, and a graphics software. A Petri dish containing 25 ml of coffe bean was placed into the lighting system that consisted of two CIE source D65 lamps 45.0 cm long, mounted on the two sides of a frame installed on either side of the Petri dish, 30.5 cm above and at an angle of 45° to the coffee bean sample plane. Images of the bottom surface of the coffe bean were taken and saved using the digital camera that was placed 30.5 cm above the sample with its lens facing down wards towards the orange juice. The color was analyzed using the Photoshop software. By turning on the grid feature in Photoshop, a grid was superimposed on the sample. As the computer pointer was placed at a grid point along the x or y axis, L, a, and b values corresponding to the pixels of that grid point were obtained from the Info Palette. The total color difference (ΔE=[(ΔL)2+(Δa)2+(Δb)2)]1/2) was determined in duplicate using CIE L, a, and b values .

2.8. total sugars and reducing sugars

Tissue (50 g) from twenty coffe bean was immediately homogenized using a blender (HR2864, Philip) for the determination of total soluble sugar and reducing sugars. Twenty-five gram aliquots of the homogenates were transferred to a beaker and 150 ml of distilledwater were added. The mixture was heated in a water bath of80 _C for 0.5 h and then filtered into a 250 ml volumetric flask. The contents were made up to 250 ml with distilled water after the addition of about 3 ml of 1 M zinc acetate and 0.25 M potassium ferrocyanide mixture. Aliquots of 10 ml were titrated to measure the contents of total soluble sugars and redureducing sugars by the Fehling's method, using glucose as reference.

2.9. Sensory evaluation

A sensorial test was run to determine packed fruit star whole quality as determined by its appearance. A panel of seven judges assessed the sensory characteristics of the investigated fresh-cut produce during the entire observation period, according to the procedure reported in the literature. Freshcut produce was used as control (score=5). The products were presented on coded plastic dishes. The intensity of the evaluated general appearance was indicated on a scale from 1 to 5, where 1–2=very poor, 3–4=fair, and 5=excellent. The sensory evaluation was used to determine the shelf life of packed produce. Scores below 3 for any of the attributes assessedwere considered as an indication of food product unacceptability. During the test sessions, the sample presentation order was randomized.

3.Result and discussion

3.1 Surface area analysis

Fig. 1 shows the nitrogen adsorption–desorption isotherms measured on nanopackaging and PE samples. The specific BETsurface areas of PE packaging and nanopackaging were 49 m2/g and 24 m2/g, respectively. The lower surface area of nanopackaging was attributed to the compact packing of the chitosan molecules in the interlayer space, resulting in pore blocking that inhibited the passage of nitrogen molecules. The average pore diameter of nanopackaging was 15.6 nm compared to 14.8 nm of PE..

3.2. Physical properties analysis of nanopackaging

Mechanical strength is generally required to maintain the structural integrity and barrier properties of films. Therefore, to provide more understanding on the physical and mechanical characteristics of this prepared film, WVP, OP and longitudinal strength were performed as a function of nanoparticles. As shown in Table 1, the WVP and OP of the pure PE films were 2768.35 cm^3m^{-2} 24 h^{-1} $(0.1\ MPa)^{-1}$ and 6.85 gm-^{2} $(24\ h)^{-1}$; as for nanocomposite films, the values decreased by 1802.13 and 4.98 respectively.

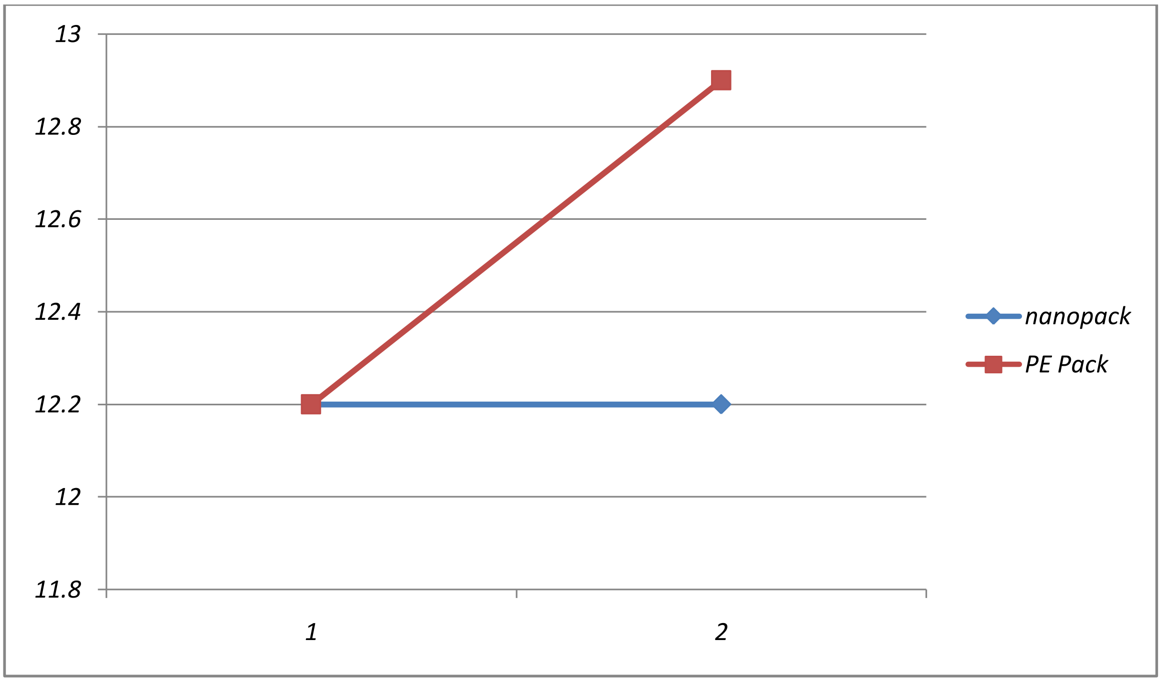
Table 1 Physical properties of nano packaging and normal packaging films.

Films	Oxygen permeability $cm^3 m^{-2}$ 24 h^{-1} (0.1 $MPa)^{-1}$	Water vapor permeability gm^{-2} (24 $h)^{-1}$	Longitudinal strength (MPa)
nanopackaging	6.85	2768.35	29.68
PE packaging	4.98	1802.13	31.96

Longitudinal strength of NCP film was 31.69% higher than the normal film. Recently the application of the nanocomposite concept had been proven to be a promising option in order to improve mechanical and barrier properties [6]. It could be inferred that the nanoparticles could affect the WVP, OP and longitudinal strength of films by the exfoliated montmorillonite which could yield significant mechanical property advantages as a modification of polymeric systems.Generally, this layered filled polymer composites exhibited extraordinary enhancement of mechanical and physicochemical properties at a low level of filler concentration in comparison to pure polymer.

3.3 water content

Coffee beans in jute sacks showed an elevated water content until the sixth month of storage. The value of water content increased, on average, between 9.80% and 11.40%. The water content remained in equilibrium with the temperature and the humidity, relative to the ambient air. The water content in the impermeable packaging remained stable at approximately 10% throughout the storage period (Fig. 2).According to Harris and Miller (2008) the water content required for secure storage is between 10% and 11%. These authors have verified that coffee beans stored in GrainPro effectively maintained a stablewater content level for four months. The results of the present study demonstrate that a stable water content level can be maintained in hermetic big bags or GrainPro for 12 months. An elevation of water content in processed beans in jute sacks can compromise quality. According to Vilela et al. (2000), the increase in water content in the green coffee during storage produces undesirable changes in the physical-chemical composition of the beans.



Storage time (month)

Fig. 2. Average values of water content for storage of green coffee. Experimental treatments: nanopackaging and Pepacaking film

3.4 Colour

Colour parameters for crude beans are presented in Table 2. Table 2 shows the changes in total color differences (ΔE=[(ΔL)2+(Δa)2+(Δb)2)]1/2) for nanpackaging compared with pure LDPE. Statistical results show significant differences ($p<0.05$) in ΔE after 7 days of storage, indicating that storage time is an important factor influencing color value and ΔE It can be observed all the nanopackages tested had a significant difference in their ΔE values after 28 days compared with pure LDPE. It is clear that ΔE values are lower for nanopackages.

Table 2 Effect of packaging on total color differences (ΔE) during 21 days storage at 25 °C.

No	Storage time (day)	ΔE	
		nanopackaging	LDPE packaging
1	0	0	0
2	7	5.62	4.62
3	14	6.14	5.12
4	21	7.93	6.88

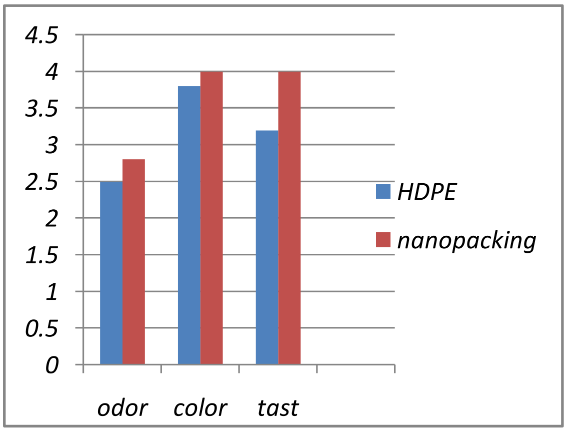
3.4. Total soluble sugars and reducing sugars

The sugar content was related to flavour quality for a variety of fruits and it determines the optimum time for harvesting. As shown in Fig. 3a, the total soluble sugars of Coffe bean with different packings continued to increase throughout the 21-day storage at room temperature. Nano-packing could significantly inhibitthe increase of total soluble sugar content compared with the control. On day 21, the total soluble sugars of the nano-packinggroup reached 28.4%, which was significantly lower than the controlof 30.0% ($P < 0.05$).Compared with the total soluble sugar content, similar trends inthe reducing sugars content were observed during room temperaturestorage (Fig. 3b). The reducing sugars content of the nanopacking group was lower than that of the control, suggesting that the coffe bean with nano-packing synthesized reducing sugars at alower rate than did the control. These results indicated that theapplication of nano-packing might be able to slow the metabolismto give prolonged storage life to the fruit.

3.7 Sensory

Fig. 5 shows the change of sensory attributes of star fruit packed in different packages. The high similarity observed in color attribute scores of the packages after 28 days of cold storage ($p<0.05$) indicates that the change in the color of the samples is still invisible.

These results correlated well with the values of browning index. Odor attribute is greatly influenced by microbial growth and may lead to fermentation in orange juice during storageAfter 15 days of storage, a significant difference is observed between the odor of star fruit packed in the test packages and that in pure package except for the onecontaining 1% nanoZnO. Changes in the taste of packed star fruit during 15 days of storage show the positive effect of nanoantimicrobial packaging. It is obvious that there is a significant difference between nano-packaging and HDPE.The sensory panelists recognized as the best packaging material in terms of overall acceptability. It is noteworthy that changing orange juice flavor during storage is not only due to thegrowth of microorganisms but also to heating, storage time, and the common chemical interactions that occur in stored juices Souza et al.[14] reported that lower storage temperatures of unpasteurized orange juice gave rise to a higher sensory acceptance than the higher temperatures for 72 h. Leizerson and Shimoni[13] reported that the sensorial shelf life of orange juice is equal to half its microbial and 2/3 its chemical shelf life.



Conclusion

In this study, a novel nano-packing material with higher barrier and mechanical properties was successfully synthesized and then applied to the preservation of star fruit during room temperature storage. The results showed that the nano-packing material had quite beneficial effects on physicochemical and physiological quality compared with normal packing material. Furthermore, these nano-packing materials have the advantages of simple processing and industrial feasibility in contrast with other storages, some of which are time-consuming, costly and alter colour and flavour.

Therefore, the nano-packing may provide an attractive alternative to improve the preservation qualities of star fruit during extended storage. Moreover, further research will be needed to explore the exact nano-packing mechanism during storage to facilitate the application of nano-technology over a broader range in the future.

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