JOURNAL OF INNOVATION FOOD AND ANIMAL SCIENCE

journal homepage: https://journal.akb.ac.id/index.php/jifas/

POTENTIAL OF ANTIOXIDANT & ANTIMICROBIAL FROM BY PRODUCT COFFEE AS EDIBLE PACKAGING: SYSTEMATIC REVIEW

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Article history:
Reviewed 10 December 2024
Revised 14 December 2024
Published 30 December 2024

Keywords:
Coffee by product;
Edible packaging;
Antioxidant;
Antimicrobial;

ABSTRACT

Plastic is still widely used to package various food products. The use of plastic has a negative impact on the environment because plastic is not easily decomposed by the soil. Edible Packaging are one solution of plastic usage for packaging. Edible packaging also has the function of maintaining the quality of its products and protecting them from microorganism contamination because it has antimicrobial and antioxidant content. Coffee by-product can be potential as edible packaging materials because have antioxidant and antimicrobial agent such as phenolic, melanoidin, caffeine, and chlorogenic acid. Antioxidants are substances that can prevent cell damage due to the oxidation process by oxidants which causes a decrease in product quality because it can change the taste, aroma, texture and rancidity of the product. Antimicrobials are substances that can inhibit or kill the growth of microbes, such as fungi, viruses, and bacteria during storage of products in packaging that can damage the product and make it less durable. Antioxidants can maintain product quality and extend product shelf life. They can act as antimicrobial which can inhibit the growth of *Listeria, Escherichia coli* and *Staphylococcus aureus* which can contaminate food. So, coffee by product can be potential if developed as edible packaging in Indonesia because the raw material is widely produced along with the many coffee plantations in Indonesia whose coffee production continues to increase due to the large number of coffee enthusiasts both in Indonesia and abroad.

1. Introduction

Based on data from the Indonesian Plastic Industry Association and the Badan Pusat Statistik (BPS), plastic waste in Indonesia reaches 64 million tons per year (Olavia, 2021). The use of plastic for packaging in Indonesia is relatively higher compared to the use of plastic for packaging globally (31.26%). Plastic is still widely used to package various food products such as snacks, bottled drinking water, frozen food, chips, tofu, tempeh, fruits, meat, vegetables, etc. However, the use of plastic has a negative impact on the environment because plastic is not easily decomposed by the soil. If plastic waste is not managed properly, it can be carried by water to rivers and then to the sea. The plastic waste will become particles called microplastics (<5 mm) which will pollute river and marine biota (Arbintarso et al., 2022).

Edible Packaging are one solution of plastic usage for packaging. Edible packaging is a food packaging that can be consumed and is made from natural materials combined with the use of technology so that it can create food packaging that can also be eaten by consumers. Edible packaging is one of the future food packages that is now starting to be introduced to the world. Natural materials that are widely used to make edible packaging are polysaccharides. Polysaccharides are complex carbohydrates consisting of chains of monosaccharide

units linked by glycosidic groups. Polysaccharides are used as edible packaging materials because they have properties that are renewable, biodegradable, and very good biocompatibility, as well as antioxidant and antimicrobial activity (Zhao, et al., 2021). Some types of polysaccharides used include starch, cellulose, hemicellulose, chitosan, pectin, alginate, carrageenan, agar and others (Zhu, 2020; Neši´c et al., 2020; Zhang et al., 2021; Chen et al., 2021; Abboud et al., 2020; Mohamed et al., 2020; Armisén & Gaiatas, 2009). Edible packaging also has the function of maintaining the quality of its products and protecting them from microorganism contamination because it has antimicrobial and antioxidant content. Both of these functions are obtained from natural materials that have functional properties as antimicrobials and antioxidants used in making edible packaging. Antioxidants are substances that can prevent cell damage due to the oxidation process by oxidants which causes a decrease in product quality because it can change the taste, aroma, texture and rancidity of the product. Antimicrobials are substances that can inhibit or kill the growth of microbes, such as fungi, viruses, and bacteria during storage of products in packaging that can damage the product and make it less durable.

In coffee fruit processing, besides coffee beans, by-products such as pulp, parchment, silverskin and spent coffee grounds are also produced. Coffee by-product can be potential as edible packaging materials because have antioxidant and antimicrobial agent such as phenolic, melanoidin, caffeine, and chlorogenic acid (Rizkaprilisa et al., 2023a). Unfortunately, the utilization of coffee by-products in Indonesia is still not widely done because they have only been thrown away or used as compost or biogas (Rizkaprilisa et al., 2023b). If this coffee by-product can be utilized, one of which is as edible packaging, it can increase the profits that can be obtained by coffee farmer and we can create environmentally friendly packaging. This article provided a review about potential antimicrobial and antioxidant of coffee by product as edible packaging for food product.

2. Methods

This article was written using a literature study method consisting of collecting references, analyzing, and concluding information from various library sources that are relevant to the topic discussed. The literature sources used in writing this article include scientific journals, books, reports, and online articles related to edible packaging, coffee by-products, antimicrobials and antioxidants. The literature sources used range from 2014 to 2024, using keywords such as "edible packaging", "coffee by-products", "antimicrobials" and "antioxidants".

3. Results and discussions

3.1. Antioxidant of Coffee By Product for Edible Packaging

Food products can experience oxidation when exposed to oxygen, causing a decrease in quality. Various research efforts have been made to limit oxidation in the form of using antioxidants. Antioxidant are substances that can prevent oxidation that causes cell damage. Nowadays antioxidants are used in packaging to protect food products during storage. The use of antioxidants in packaging to keep food products more durable because the packaging used can protect it from oxidation that can occur due to environmental factors or the product itself. The working principle of antioxidants in packaging is the release of antioxidants into the packaged food product and the prevention of unwanted compounds such as oxygen, radical oxidative species or metal ions from the environment or from food (Gomez-Estaca. Et al., 2014). So, the use of antioxidants in packaging can increase food stability, extend shelf life, prevent rancidity, and slow down color and aroma changes.

Antioxidant materials used in packaging are synthetic and natural. The synthehtic antioxidant material was used such as BHT, BHA, EDTA, BHA, PG, and TBHQ (Ortiz-Vazquez et al., 2011; Jamshidian et al., 2012; Ünalan et al., 2011). Meanwhile, natural antioxidant materials come from plant extract and essential oil. In the making of edible packaging, they are added to the polymer matrix or on its surface. The polymer matrix are polysaccharides such as starch, cellulose, hemicellulose, chitosan, pectin, alginate, carrageenan, agar and others.

Coffee by products have high antioxidant component that be potential for edible packaging that can maintain product quality and extend product shelf life. Coffee by products such as husk, pulp, parchment, silverskin, and spent coffee ground. They contain antioxidant components include tannin, chlorogenic acid, flavonoids, phenolic, caffeine, and caffeic acid (Setiawan et al., 2024). Several studies that utilize antioxidant components of coffee by-products as edible packaging can be seen in **Table 1**. This research show that antioxidant from coffee by product can utilized as edible packaging material

because they have advantage such as biodegradable, biocompatible, and readily decomposable in the environment (Vengatesan et al., 2021). So, coffee by product can be pottential if developed as food packaging in Indonesia because the raw material is widely produced along with the many coffee plantations in Indonesia whose coffee production continues to increase due to the large number of coffee enthusiasts both in Indonesia and abroad.

Table 1. Coffee By Products as Antioxidant in Edible Packaging

Coffee By Product	Polymer Matrix	Antioxidant Component		Reference
Husk	Polybutylene Adipate Terephthalate	Tannin (g/100 g) Chlorogenic acid (mg/g) Total flavonoids (mg QE/100 g) Total phenolic content (mg GAE/100 g) Caffeine (µg/g)	4.5–8.6 1.7–3.9 7–8.47 384 – 455 1327–9816	Lule et al., 2021; Brand et al., 2000; Iriondo-DeHond et al., 2019; Rebollo-Hernanz et al., 2019; Das Neves et al., 2019
Pulp	Chitosan	Tannin (g/100 g) Chlorogenic acid (mg/g) Total flavonoids (mg QE/100 g) Total phenolic content (mg GAE/100 g) Caffeine (mg/g)	3.5–6 2.6 - 255–453 18.6–31	Sung et al., 2017; Ameca et al., 2018; Delgado et al., 2019
Parchment	Gellan gum	Tannin (g/100 g) Chlorogenic acid (µg/g) Total flavonoids (mg QE/100 g) Total phenolic content (mg GAE/100 g) Caffeine (mg/g)	1.7 232.6 - 228–284 -	Mirón-Mérida et al., 2019; Negesse et al., 2009; Iriondo-DeHond et al., 2019
Silverskin	Corn Starch	Tannin (g/100 g) Chlorogenic acid (µg/g) Total flavonoids (mg QE/100 g) Total phenolic content (mg GAE/100 g) Caffeine (mg/g)	3.45 9.4 2.73 10.75–17.3 10–36	Oliveira et al., 2020; Saada et al., 2019; Iriondo-DeHond et al., 2019; Rebollo-Hernanz et al., 2019; Regazzoni et al., 2016
Spent Coffee Ground	Galactomannans	Tannin (g/100 g) Chlorogenic acid (µg/g) Total flavonoids (mg QE/100 g)	0.997 6 2.11–8.29	Batista et al., 2020; Saada et al., 2019; Panusa et al.,

		Total phenolic content (mg GAE/100 g) Caffeine (mg/g)	12.29–19.2 49–73	2013; Conde & Mussatto, 2016; Jim´enez-Zamora et al., 2015; Monente et al., 2015

3.2. Antimicrobial of Coffee By Product for Edible Packaging

Antimicrobial are a substance that can inhibit or kill the growth of microorganisms, such as bacteria and fungi. Food product can be experiencing decay caused by biological contamination from microorganisms such as *E. coli, Pseudomonas, Clostridium botulinum, Staphylococcus aureus, Bacillus subtilis, Listeria monocytogenes, Salmonella and others.* They can cause the shelf life of the product to become less durable. In addition to food processing techniques and the use of preservatives that can protect food from microorganism contamination, the use of packaging that has antimicrobial properties will increase food protection so that the quality of food products can be maintained during storage in packaging until they reach consumers.

Coffee by product have antimicrobial agent because the antioxidant component can act as antimicrobial activity such as phenolic, chlorogenic acid and caffeine (Cendekia et al, 2020). Several studies have research the potential of coffee by-products as antimicrobials (**Table 2**). *Listeria* is a bacteria that can contaminate food and cause an infection that cause mild symptoms, such as nausea and diarrhea, to severe symptoms, such as inflammation of the brain. *Eschericia coli* is bacteria that normally live in the intestines of humans and animals, whose function is to maintain a healthy digestive system, but these bacteria can cause infections because they can produce toxins that cause symptoms of diarrhea, stomach ache and cramps.

The toxin from the *Escherichia coli* bacteria can be transmitted to humans through the consumption of contaminated food such as raw or undercooked meat, raw milk, and contaminated raw vegetables. *Staphylococcus aureus* can contaminate various types of food such as poultry and meat, milk and milk products, canned foods, and bakery products. These bacteria can cause infections that cause symptoms of nausea, vomiting, abdominal pain, diarrhea, headache, weakness, fever. So, one of the efforts to protect food from contamination by microorganisms that can reduce the quality of food products and cause decay is by using packaging that has antimicrobials. This antimicrobial packaging will protect food through antioxidant components contained in the packaging material that can prevent contamination by microorganisms.

Table 1. Coffee By Product as Antimicrobial in Edible Packaging

Coffee By Product	Microbial	Result of research	Reference
Husk	*Listeria innocua* and *Eschericia coli*	Coffee and rice husks extracts exhibited antioxidant properties (EC_{50}: 5.37–5.29 mg extract solids/mg DPPH) and antibacterial activity against *Listeria innocua* and *Escheriquia coli* (MIC values: 35–45 and 34–35 mg extract solids/mL, respectively).	Collazo-Bigliardi et al., 2019
Silverskin	*Staphylococcus aureus*	The antibacterial activity of Robusta coffee bean	Cendekia et al, 2020

		extract with a concentration of 75% resulted in an inhibition zone diameter greater than other concentrations of 1.22 mm.	
Spent Coffee Ground	*Escherichia coli* and *Staphylococcus aureus*	The synergetic effect on antibacterial activity was observed in 10 wt% of spent coffee ground (SFE-10) with 8 wt% oregano essential oil. The sample had the minimum inhibitory concentration against *E. coli* and *S. aureus*.	Trongchuen et al., 2017
	Escherichia coli and *Staphylococcus aureus*	The PVA/starch incorporated ex-SCG (PSt-E) film incorporated 30 wt% citric acid showed minimum inhibitory concentration against *Escherichia coli* (*E. coli*) and *Staphylococcus aureus* (*S. aureus*). The incorporation of ex-SCG and citric acid into film showed a synergistic effect on antibacterial activity.	Ounkaew et al., 2018

4. Conclusions

Coffee by products such as husk, pulp, parchment, silverskin, and spent coffee ground. They contained antioxidant components include tannin, chlorogenic acid, flavonoids, phenolic, caffeine, and caffeic acid. It can maintain product quality and extend product shelf life. In addition, antioxidants component in coffee products also have antimicrobial activity which can inhibit the growth of *Listeria*, *Escherichia coli* and *Staphylococcus aureus* which can contaminate food. So, coffee by product can be pottential if developed as edible packaging in Indonesia because the raw material is widely produced along with the many coffee plantations in Indonesia whose coffee production continues to increase due to the large number of coffee enthusiasts both in Indonesia and abroad.

5. References

Abboud, K.Y., Lacomini, M., Simas, F.F., Cordeiro, L.M.C. 2020. High methoxyl pectin from the soluble dietary fiber of passion fruit peel forms weak gel without the requirement of sugar addition. *Carbohydr. Polym*., 246, 116616.

Ameca, G.M., Cerrilla, M. E. O., C´ordoba, P. Z., Cruz, A. D., Hern´andez, M.S., Haro, J.H. 2018. Chemical composition and antioxidant capacity of coffee pulp. *Ciencia E Agrotecnologia*, 42(3), 307–313.

Arbintaso, E.S., Erna, K.N. 2022. The family role in improving environmental quality through domestic plastic waste recycling. *Berdaya Mandiri Journal*, 4 (3), 300-318

Armisén, R., Gaiatas, F. 2009. 4-Agar. In *Handbook of Hydrocolloids*, 2nd ed.; Phillips, G.O., Williams, P.A., Eds. Sawston UK: Woodhead Publishing.

Batista, M.J.P.A., Ávila, A.F., Franca, A.S., Oliveira, L.S. 2020. Polysaccharide-rich fraction of spent coffee grounds as promising biomaterial for films fabrication. *Carbohydr. Polym*., 233, 115851

Brand, D., Pandey, A., Roussos, S., Soccol, C.R. 2000. Biological detoxification of coffee husk by filamentous fungi using a solid-state fermentation system. *Enzyme and Microbial Technology*, 27(1–2), 127–133

Cendekia, D., Analianasari, Widia, H. 2020. Utilization of coffee silverskin as natural antimicrobial in *Staphylococcus aureus* bacteria. *International Conference on Agriculture and Applied Science* (ICoAAS), 50-54

Chen, X., Pang, J., Wu, C. 2021. Fabrication and characterization of antimicrobial food packaging materials composed of konjac glucomannan, chitosan and fulvic acid. *Food Sci*., 42, 232–239

Collazo-Bigliardi, S., Ortega-Toro, R., Amparo, C. 2019. Improving properties of thermoplastic starch films by incorporating active extracts and cellulose fibres isolated from rice or coffee husk. Food *Packaging and Shelf Life*, 22, 100383

Conde, T., Mussatto, S.I. 2016. Isolation of polyphenols from spent coffee grounds and silverskin by mild hydrothermal pretreatment. *Preparative Biochemistry & Biotechnology*, 46(4), 406–409

Das Neves, J.V.G., Borges, M.V., de Silva, D., M., Leite, C.X.D.S., Santos, M.R.C. 2019. Total phenolic content and primary antioxidant capacity of aqueous extracts of coffee husk: Chemical evaluation and beverage development. *Food Science and Technology*, 39, 348–353

Delgado, S.R., Arbelaez, A.F.A., Rojano, B. 2019. Antioxidant capacity, bioactive compounds in coffee pulp and implementation in the production of infusions. *Acta Science Polumer Technology Aliment*, 18(3), 235–248

Gomez-Estaca, J., Lopez-de-Dicastillo, C., Hernandez-Munoz, P., Catala, P., Gavara, R. 2014. Advances in antioxidant active food packaging. *Trends in Food Science & Technology*, 35(1), 42–51.

Iriondo-DeHond, A., Aparicio García, N., Fernandez-Gomez, B., Guisantes-Batan, E., Vel´azquez Escobar, F., Blanch, G.P. 2019. Validation of coffee by-products as novel food ingredients. Innovative *Food Science & Emerging Technologies*, 51, 194–204.

Jamshidian, M., Tehrany, E.A., Desobry, S. 2012. Release of synthetic phenolic antioxidants from extruded poly lactic acid (PLA) film. *Food Control,* 28(2), 445–455.

Jim´enez-Zamora, A., Pastoriza, S., Rufi´an-Henares, J.A. 2015. Revalorization of coffee by-products. Prebiotic, antimicrobial and antioxidant properties. *Lebensmittel-Wissenschaft und-Technologie-Food Science and Technology*, 61(1), 12–18.

Lule, Z.C. Kim, J. 2021. Properties of economical and eco-friendly polybutylene adipate terephthalate composites loaded with surface treated coffee husk. *Compos. Part A Appl. Sci. Manuf*.,140, 106154.

Mirón-Mérida, V.A., Yáñez-Fernández, J., Montañez-Barragán, B., Barragán Huerta, B.E. 2019. Valorization of coffee parchment waste (*Coffea arabica*) as a source of caffeine and phenolic compounds in antifungal gellan gum films. *LWT Food Science*, 101, 167–174.

Mohamed, S.A.A., El-Sakhawy, M., El-Sakhawy, M.A.-M. 2020. Polysaccharides, protein and lipid -based natural edible films in food packaging: A review. *Carbohydr. Polym*., 238, 116178.

Monente, C., Bravo, J., Vitas, A.I., Arbillaga, L., de Pe˜na, M.P., Cid, C. 2015. Coffee and spent coffee extracts protect against cell mutagens and inhibit growth of food-borne. *Journal of Functional Foods*, 12, 365–374

Negesse, T., Makkar, H.P.S., Becker, K. 2009. Nutritive value of some non-conventional feed resources of Ethiopia determined by chemical analyses and an in vitro gas method. *Animal Feed Science and Technology*, 154(3–4), 204–217

Neši´c, A., Cabrera-Barjas, G., Dimitrijevi´c-Brankovi´c, S., Davidovi´c, S., Radovanovi´c, N., Delattre, C. 2020. Prospect of polysaccharide based materials as advanced food packaging. *Molecules,* 25, 135

Olavia, L. 2021. Kurangi Pemakaian Plastik Hingga 9,5%. Retrieved from: https://investor.id/lifestyle/239672/2021-kurangi-pemakaian-plastik-hingga-95

Oliveira, G., Gonçalves, I., Barra, A., Nunes, C., Ferreira, P., Coimbra, M.A. 2020. Coffee silverskin and starch-rich potato washing slurries as raw materials for elastic, antioxidant, and UV-protective biobased films. *Food Res. Int*., 109733

Ortiz-Vazquez, H., Shin, J., Soto-Valdez, H., Auras, R. 2011. Release of butylated hydroxytoluene (BHT)

from poly (lactic acid) films. *Polymer Testing*, 30(5), 463–471.

Panusa, A., Petrucci, R., Lavecchia, R., Zuorro, A. 2017. UHPLC-PDA-ESI-TOF/MS metabolic profiling and antioxidant capacity of arabica and robusta coffee silverskin: Antioxidants vs phytotoxins. *Food Research International*, 99, 155–165.

Rebollo-Hernanz, M., Zhang, Q., Aguilera, Y., Martín-Cabrejas, M. A., de Mejia, G.E. 2019. Phenolic compounds from coffee by-products modulate adipogenesis-related inflammation, mitochondrial dysfunction, and insulin resistance in adipocytes, via insulin/PI3K/AKT signalling pathways. *Food and Chemical Toxicology*, 132, 110672.

Regazzoni, L., Saligari, F., Marinello, C., Rossoni, G., Aldini, G., Carini, M. 2016. Coffee silver skin as a source of polyphenols: High resolution mass spectrometric profiling of components and antioxidant activity. *Journal of Functional Foods*, 20, 472–485

Rizkaprilisa, W., Martina. W. H., Ratih, P., Suci, A. P. 2023a. Improvement of bread nutrition with the addition of coffee silverskin as a source of dietary fiber and antioxidants. *Food ScienTech Journal*, 5 (2)

Rizkaprilisa, W., Martina. W.H., Ratih, P., Santosa, K.M. 2023b. Production of high dietary fiber and antioxidant activity bread from coffee parchment skin flour. *Coffee Science*, 182121

Setiawan, S. C. A., Arri, Y., Riskaprilisa, W., Ratih, P. 2024. Potential of dietary fiber and antioxidants from coffee skin as a food product in preventing obesity: Systematic review. science, *Technology and Management Journal*, 4 (1), 16-21

Sung, S.H.; Chang, Y., Han, J. 2017. Development of polylactic acid nanocomposite films reinforced with cellulose nanocrystals derived from coffee silverskin. *Carbohydr. Polym*., 169, 495–503.

Trongchuen, K., Artjima, O., Pornnapa, K., Salim, H., Wiyada, M., Rungnapha, W., Uraiwan, P., & Prinya, C. 2017. Bioactive starch foam composite enriched with natural antioxidants from spent coffee ground and essential oil. *Starch - Stärke*, 70(7–8), 1700238.

Ounkaew, A., Kasemsiri, P., Kamwilaisak, K. *et al.* 2018. Polyvinyl Alcohol (PVA)/starch bioactive packaging film enriched with antioxidants from spent coffee ground and citric acid. *J Polym Environ* 26, 3762–3772

Ünalan, ˙I. U., Korel, F., Yemenicio˘glu, A. 2011. Active packaging of ground beef patties by edible zein films incorporated with partially purified lysozyme and Na2EDTA. *International Journal of Food Science and Technology*, 46(6), 1289–1295.

Vengatesan M., Rangaraj, K., Rambabu, & Fawzi B., Vikas, M. 2021. Natural antioxidants-based edible active food packaging: An overview of current advancements. *Food Bioscience*, 43, 101251

Zhang, Y., Li, B., Xu, F., He, S., Zhang, Y., Sun, L., Zhu, K., Li, S., Wu, G., Tan, L. 2021. Jackfruit starch: Composition, structure, functional properties, modifications and applications. Trends *Food Sci. Technol*., 107, 268–283

Zhao, Y., Li, B., L,i C., Xu, Y., Luo, Y., Liang, D., & Huang, C. 2021. comprehensive review of polysaccharide-based materials in edible packaging: A sustainable approach. *Foods*, 10(8):1845.

Zhu, F. 2020. Underutilized and unconventional starches: Why should we care? *Trends Food Sci*. *Technol*., 100, 363–373.