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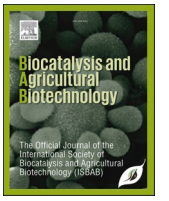

Utilization of fruit waste substrates in mushroom production and manipulation of chemical composition

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ABSTRACT

The current study evaluated the effect of mushroom cultivation using fruit waste substrates on yield performance and antioxidant activities. The total phenolic content and the 2, 2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activities of the mushroom extracts were determined using colorimetric method. Mushroom *P. eryngii* had the highest yield of 87.2 ± 2.4 g/100 g dry substrate when grown on pineapple peels, while *P.ostreatus* yielded the least fruiting bodies 53.1 ± 1.8 g/100 g dry substrate when grown on orange peels. Similarly, *P. eryngii* grown on pineapple peels and *P. ostreatus* grown on orange peels had the highest and lowest biological efficiencies of 94.2 ± 3.5% and 69 ± 4.3%, respectively. The total phenolic content of *P.ostreatus* grown on avocado peels was 26.4 ± 3.8 mg GAE/g dry extract, while *P.eryngii* grown on avocado peels had the lowest at 9.3 ± 0.2 mg GAE/g dry extract. Mushrooms cultivated on fruit wastes generally exhibited higher DPPH activities than those grown on wheat straw (control) substrate. This study provided baseline information on the potential role of fruit waste substrates in mushroom growth and chemical composition.

1. Introduction

Edible mushrooms have been a part of human culture since time immemorial. They have made significant contributions to the history of human civilization (Dhar, 2017; Comandini and Rinaldi, 2020). Edible species have long been popular due to their sensory qualities and appealing culinary qualities. Mushrooms are in high demand these days because of their numerous nutritional and health benefits. They have a high protein, vitamin, and mineral content and are low in calories, carbohydrates, fat, and sodium (Fulgoni and Agarwal, 2021). Many life-threatening diseases such as Parkinson's, Alzheimer's, hypertension, and stroke were managed by consuming mushrooms (Boa, 2004). Similarly, mushrooms have found widespread applications in conventional medicine. Many compounds such as flavonoids, phenolic acids, stilbenes, coumarins, lignans, tannins, and other bioactive compounds present in mushrooms contribute to their functional properties (Roupas et al., 2012). These substances are well-known for their antimicrobial, immune-boosting, and cholesterol-lowering abilities. They are considered therefore as important functional foods, and dietary supplements (Zeb and Lee, 2021).

Depending on the species, mushrooms can have symbiotic or parasitic relationships with plants, and some, such as saprophytes, can feed on dead or decaying plant materials (Hou et al., 2012).They have ability to produce extracellular enzymes that break-down

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lignocellulosic materials into simple sugars during growth and development. During the rainy season, mushrooms were traditionally collected from rotten or rotting logs of wood in forests and open grounds. However, with advancements in science and technology, many species of can now be commercially produced under controlled artificial conditions using a wide range of agricultural residues as growth substrates.

The plant residues such as paddy and wheat straws/brans, sugarcane bagasse, sawdust, corn cob and stover, coffee husks have been used as low-cost substrates for mushroom cultivation (Sánchez, 2010). Similarly, by products of fruit and vegetable processing can be used to produce value-added products under the circular economy concept (Grimm et al., 2018). Despite high concentrations of soluble sugars and other high-value biomolecules, wastes from fruit processing and postharvest handling are still regarded as environmental pollutants, particularly in the developing countries (Fernández-López et al., 2020). At least 1.3 billion metric tons of fruit and vegetable wastes are produced every year as a result of the supply and handling chain, which includes during harvesting, transportation, classification and grading, storage, marketing, processing, and at home before or after preparation (Gustavsson et al., 2011). The vast majority of these wastes end up in landfills, where they contribute to greenhouse gas emissions that contribute to global warming. However, due to concerted research efforts, fruit and vegetable wastes are receiving increased attention in mushroom production due to their potential to improve yield, as well as nutritional and chemical composition in mushrooms (Ekwe et al., 2020; Di Piazza et al., 2021; Tavarwisa et al., 2021). The present study evaluated the growth performance and antioxidant activities of edible mushrooms grown using different fruit waste materials.

2. Materials and methods

2.1. Production of mushroom fruiting bodies

The cultures of *Pleurotus sajor-caju* (Fr.) Singer, *Pleurotus ostreatus* (Jacq.:Fr.) P. Kumm., and *Pleurotus eryngii* (DC.) Quel., were obtained from the Food Research Division at the Kenya Industrial Research, and Development Institute, Nairobi, Kenya. Peels from the processing of mangoes (*Mangifera indica*), bananas (*Musa acuminata*), pineapples (*Ananas comosus*), avocados (*Persea americana*), oranges (*Citrus reticulata*), and watermelon (*Citrullus lanatus*) were obtained from the local fruit vendors in Nairobi, Kenya. Wheat (*Triticum aestivum*) straw was used as control substrate. The sterilized substrates were inoculated with three-day-old mushroom cultures. Cultivation was performed under controlled conditions of relative humidity (55–60%), temperature (23–25 °C), and relative light intensity (12 h). Fruiting bodies were harvested and oven-dried for 24 h at 50 °C after each flush. The biological efficiency (%) of mushrooms used was determined as follows:

$$\mathrm{BE}\cdot(\%) = \frac{Total\ mushroom\ fresh\ weight(g) across\ 3\ flushes}{Substrate\ dry\ weight\ (g)} \times 100$$

2.2. Preparation of mushroom extracts

The dried fruiting bodies were ground into a fine powder using a 0.5 mm sieve. The powder (1 g) was soaked overnight in 50 ml distilled water before being sonicated for 2 h at 60 °C in an ultrasonic bath. The sample passed through Whatman No. 1 filter paper, was evaporated to a constant mass in a stream of warm air. The procedure was repeated three times, and the recovered extracts were combined and stored in an airtight plastic container. The extract yield was obtained by subtracting the weight of the empty evaporation flask from that of the glass containing the extract.

The total phenolic content of the extracts, expressed as gallic acid equivalents (GAEs), was determined using a modified method by Naczk and Shahidi (2004). One milliliter of the sample was mixed with 1 ml of the Folin-phenol Ciocalteu's reagent (Sigma). After 3 min of incubation at room temperature, 1 ml of 35% (w/v) Na_2CO_3 was added to the mixture, which was topped up to 10 ml with distilled water. After 90 min in the dark, the absorbance of the reaction was measured at 725 nm. A calibration curve was created using various concentrations of gallic acid (Sigma).

2.3. Determination of antioxidant activities

The radical scavenging activity of mushroom extracts on 1, 1-diphenyl-2-picrylhydrazyl (DPPH) radicals was measured using a procedure modified from Chu et al. (2000). In a test tube with 1 ml of extract, an aliquot of 0.5 ml of 0.1 mM DPPH (Sigma) was added. The reaction mixture was vortexed at room temperature, and the absorbance at 520 nm was measured. The DPPH scavenging activity (SA) was calculated as a percentage (Equation (1)). Gallic acid was used as a control.

$$SA\cdot(\%) - (1 - \frac{\mathrm{Abs}\ \ (\mathrm{control}) - \mathrm{Abs(sample)}}{\mathrm{Abs}\ \ \mathrm{control}}) \times 100 \quad (1)$$

where Abs_o = Absorbance of the control solution containing only DPPH solution; A_1 = Absorbance in the presence of extract in DPPH solution.

2.4. Statistical analysis

All the analyses were performed in triplicates. The data were recorded as means standard deviations and analyzed by SPSS (SPSS Inc.). One-way analysis of variance (ANOVA) and Tukey multiple comparisons were carried out to test for any significant differences between the means. Correlations were obtained by Pearson correlation coefficient in bivariate correlations. Differences between means at 5% ($P < 0.05$) level were considered significant.

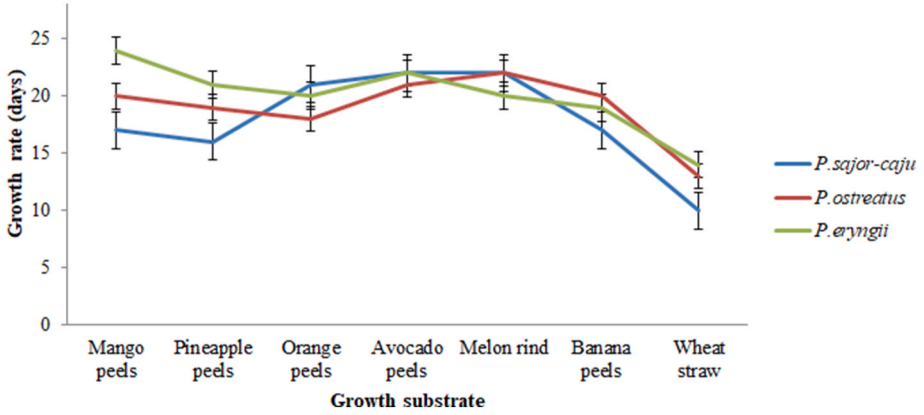

Fig. 1. Days to pinhead formation of mushrooms grown using fruit waste substrates.

Table 1
Proximate composition of mushroom growth substrates used in this study.

Substrates	Composition in g/100 g of dry peel					Dietary fibre content (%) dry mass			References
	Total crude protein	Total crude Lipids	Ash	Crude fibers	Carbo-hydrates	Lignin	Hemi-cellulose	Cellulose	
Mango peel	5.00 ± 0.09	4.72 ± 0.55	3.24 ± 0.18	15.43 ± 0.13	63.80 ± 0.16	3.0	14.0	12.0	Feumba et al. (2016) Orozco et al. (2014)
Orange peel	9.73 ± 0.63	8.70 ± 0.65	5.17 ± 0.98	14.19 ± 0.01	53.27 ± 0.10	2.0	6.0	14.0	Feumba et al., (2016); Hussein et al. (2020)
Pineapple peel	5.11 ± 0.02	5.31 ± 0.74	4.39 ± 0.14	14.80 ± 0.01	55.52 ± 0.92	10.0	31.0	21.0	Feumba et al., (2016); Banerjee et al. (2019)
Avocado peel	7.04 ± 0.00	1.05 ± 0.01	3.07 ± 0.00	2.98 ± 0.00	80.75 ± 0.04	2.0	50.0	7.0	Egbuonu(2015); Dávila et al. (2017)
Watermelon rind	12.42 ± 0.08	12.61 ± 0.63	5.03 ± 0.80	26.31 ± 0.01	32.16 ± 1.22	10.0	23.0	20.0	Banerjee et al.(2016); Feumba et al., (2016)
Banana peels	10.44 ± 0.38	8.40 ± 1.15	12.45 ± 0.38	11.81 ± 0.06	43.40 ± 0.55	14.0	20.0	26.0	Feumba et al., (2016); Hussein et al. (2020)
Wheat straw	2.95 ± 0.116	1.4	5.9	41.6	45.72 ± 0.81	15.0	35.0	40.0	Pasha et al. (2013) Shrivastava et al. (2014)

3. Results and discussion

3.1. Growth rate

The production of edible mushrooms at a commercial scale using cellulose, hemicellulose, and lignin-rich agro-residues such as paddy and wheat straws/brans, sugarcane bagasse, sawdust, corn cob and stover, coffee husks, etc. has been reported (Sánchez, 2010). However, only a few or probably no studies have reported the production of edible mushrooms using fruit waste materials. In the present study, the potential of fruit waste substrates to improve mushroom growth rate has been demonstrated in Fig. 1.

The growth rate of *P.sajor-caju*, *P.ostreatus*, and *P.eryngii* was performed on peels from processing of mangoes, pineapples, oranges, avocado, watermelon rind, and banana as sole growth substrates. The interim period to pinhead formation varied depending on the mushroom species and the growth substrates used. The time taken to form pinheads was shortest (11 days) when *P.ostreatus* was grown on the orange peel substrates. This was comparable to the period taken by the *P.sajor-caju* grown on the control wheat straw (control) substrate to form pinheads. It took longest period (17 days) for *P.sajor-caju* grown on the mango and avocado peels respectively and *P. eryngii* grown on the mango peels to form pinheads. The period taken by the mushrooms to form pinheads on wheat straw substrates was generally less compared to the time taken to form pinheads on the fruit waste substrates. This could be attributed to the chemical constituents of the fruit peels which have antifungal properties. The presence of increased amount of antifungal compounds in fruit wastes might be responsible for slowing down mushroom growth (Narender et al., 2017; Olakunle et al., 2019). However, the growth rate was faster once the pinheads were formed suggesting that the mushrooms were able to quickly adapt to the chemical environments of the fruit waste substrates.

3.2. Mushroom yield

The nutrient composition of different mushroom growth substrates has been widely studied. Table 1 illustrates literature information on the proximate composition of mushroom growth substrates used in this study.

Mushroom yield in this study depended on strain and growth substrate used. The yield has been illustrated in Fig. 2.

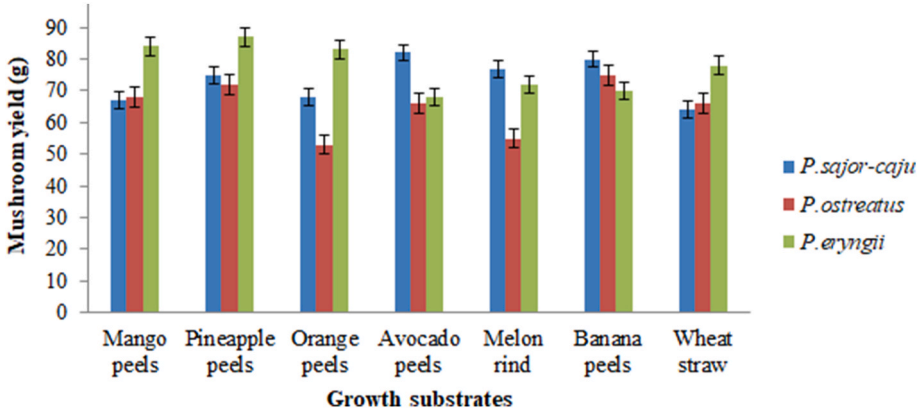

Fig. 2. Yields of *Pleurotus* species grown using fruit waste substrates.

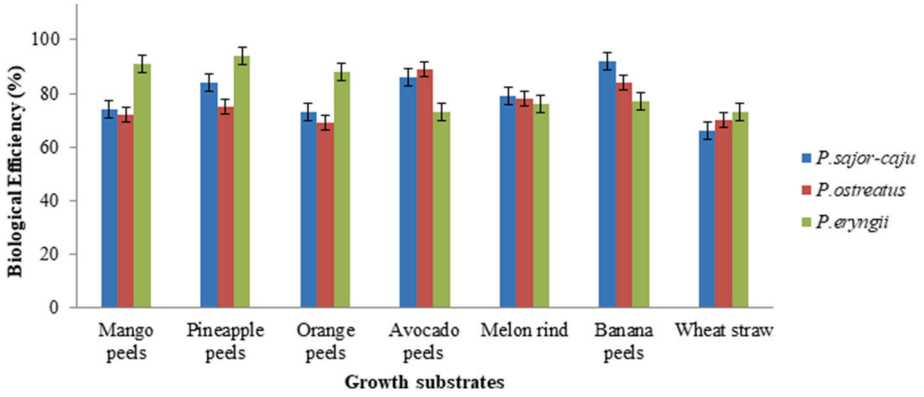

Fig. 3. Biological efficiencies (%) of *Pleurotus* species grown using fruit waste substrates.

P.eryngii had the highest yields of 87 g/100 g dry pineapple peels and 84 g/100 g dry mango peels. The least yields of 53 g/100 g dry orange peels and 55 g/100 g dry water melon rind were obtained from *P.ostreatus*. The highest mushroom yield on wheat straw was recorded in *P.eryngii* (78 g/100 g dry substrate) while the lowest (64 g/100 g dry substrate) yield was recorded in *P.sajor-caju*. The results in this study compare well with those of *P.ostreatus* cultivated on sawdust, *P. sajor-caju* and *P. columbinus* cultivated on cardboard respectively Mandeel et al., 2005). Likewise, our findings agreed with the studies conducted by Singh and Singh (2012) and Shashitha et al. (2016), in which *Pleurotus sapidus* and *Pleurotus ostreatus* exhibited good yield on vegetable wastes such as carrot pomace, radish potato, cucumber, and onion peels. The observed high yields of mushrooms grown using fruit wastes resulted from high nutrients and soluble sugars present in the fruit waste materials (Table 1). Furthermore, mushrooms have the ability to break down hemicellulosic and cellulosic materials in fruit waste substrates using extracellular enzymes, releasing more nutrients for growth and development. This is in contrast to conventional wheat or paddy straw substrates, which contain fewer nutrients and are more difficult for mushroom extracellular enzymes to hydrolyze. However, with the concept of circular economy, fruit wastes can be integrated into the mushroom production circle thereby reducing environmental pollution while increasing real benefits to farmers. If, as indicated in this study that an average of 50 g of mushroom can be produced from 100 g of fruit wastes, then it implies that over 1.3 million metric tons of fruit wastes which are reportedly generated globally every year when well-formulated can provide over 100 million metric tons of healthy edible mushrooms to the global food basket.

3.3. Biological efficiency of mushrooms on fruit waste materials

The *Pleurotus* species used in this study exhibited varied biological efficiencies (BE) in relation to the mushroom species and the fruit waste substrates used. Fig. 3 illustrates biological efficiencies of mushrooms grown using different substrates. The mushrooms cultivated using fruit waste substrates had relatively higher biological efficiency than those on the wheat straw substrates.

The *Pleurotus eryngii* grown on pineapple peels exhibited the highest BE of 94.2 ± 3.5% followed by *P.sajor-caju* grown on banana peels which had BE of 92.7 ± 2.3%. The *P.ostreatus* grown on mango peels had the lowest BE of 72.4 ± 1.8%. The highest and lowest BE of 73.5 ± 2.6% and 66.8 ± 3.4% was reported in *P.eryngii* and *P. sajor-caju* grown on wheat straw substrates respectively. The BE in the present study agreed with the previous report by Koutrotsios et al. (2014) where *P. ostreatus* cultivated on corn cobs, and wheat straw had BE of 52.82% and 66.93% respectively and the *P.ostreatus* grown on sisal wastes enriched with cow manure had BE of 62.9%. The high BE recorded in this study suggested that the fruit waste substrates were rich in macromolecules such as proteins, lipids,

Table 2
Total aqueous extracts and phenolic contents from mushrooms grown using different fruit waste substrates.

Mushroom species	Extracts	Growth substrates						
		Mango	Pineapples	Oranges	Avocado	Melon	Banana	Straw
P. sajor-caju	TAE (mg/g)	82.2 ± 0.1	67.4 ± 0.2	63.5 ± 0.7	86.3 ± 0.4	65.1 ± 0.1	80.6 ± 0.5	60.6 ± 0.3
	TPC (mg ^{b}GAE/g)	21.5 ± 1.3	15.8 ± 0.9	15.9 ± 0.7	19.9 ± 0.5	14.3 ± 1.2	18.5 ± 1.4	15.6 ± 0.8
P. ostreatus	TAE (mg/g)	90.4 ± 0.5	88.6 ± 3.6	82.8 ± 4.2	100.4 ± 4.8	76.8 ± 3.1	75.4 ± 4.8	52.4 ± 0.6
	TPC (mg ^{b}GAE/g)	22.4 ± 2.4	20.8 ± 3.8	16.3 ± 2.2	26.4 ± 3.8	12.8 ± 1.6	13.5 ± 2.1	10.2 ± 3.2
P. eryngii	TAE (mg/g)	98.2 ± 5.4	79.4 ± 4.3	77.2 ± 2.2	82.8 ± 3.4	69.2 ± 1.8	60.2 ± 3.2	57.2 ± 0.3
	TPC (mg GAE/g)	24.6 ± 2.4	18.4 ± 4.3	20.4 ± 2.8	9.3 ± 0.2	16.3 ± 2.4	12.1 ± 0.8	13.6 ± 1.4

Total Aqueous Extracts (TAE) represented in mg per gram of mushroom on dry weight basis. Total phenolic content, TPC (GAEs, gallic acid equivalents).Values expressed are means ± S.D. of triplicate measurements. Means were significantly different ($P < 0.05$, ANOVA, Turkey-HSD).

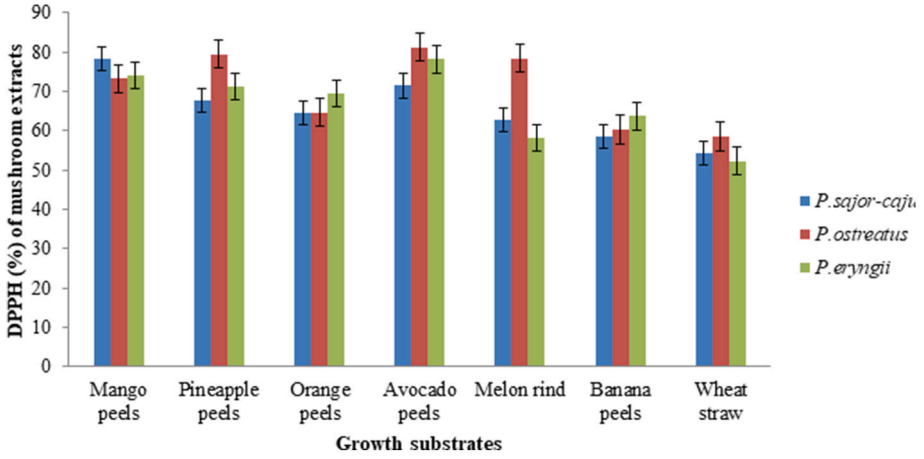

Fig. 4. DPPH radical scavenging activities of extracts from mushrooms grown on fruit waste.

carbohydrates and other chemicals (Table 1) which mushrooms were well able to utilize for their growth and development (Romelle et al., 2016). The nutrients are however limited in the wheat straws; mushrooms therefore have to hydrolyze the straws by extra-cellular enzymes to access more nutrients for growth. This explains the low BE observed in mushrooms grown on wheat straw substrates (Kumla et al., 2020). The high biological efficiency observed when mushrooms are cultivated on fruit wastes suggests that bioconversion of fruit wastes by mushrooms is effective and can be adopted as a profitable approach to fruit waste management.

3.4. Total phenolic content

Phenolic compounds are secondary metabolites which are produced in plants through phenylpropanoid metabolization (Shetty, 2004). They play different roles in plant life including acting as structural polymers, antioxidants, attractants and defense response chemicals (Kähkönen et al., 1999). They have therefore special applications in human and animal medicine such as in modulating animal and human defense responses including anti-aging, anti-inflammatory, antioxidant and anti-proliferative activities. The total aqueous extracts (TAE) obtained from the mushrooms grown using fruit waste and wheat straw is illustrated in Table 2. The total extracts depended on the mushroom species and the fruit waste substrates used for their production. The high quantities of the aqueous extracts obtained in this study were attributed to the presence of high levels of hydrophilic components in mushrooms grown on fruit waste substrates(Alispahić et al., 2015). The highest (100.3 ± 4.2 mg/g dry mushroom) quantity of TAE was recorded in *P.ostreatus* grown on avocado peels whereas the lowest (51.6 ± 2.5 mg/g dry mushroom) was obtained from *P.sajor-caju* grown on orange peels. The mushrooms grown on the wheat straw (control) substrate produced less aqueous extract, with *P.sajor-caju* producing the most (60.8 ± 3.2 mg/g dry mushroom) and *P.ostreatus* producing the least (52.4 ± 1.8 mg/g dry mushroom). The preparation of aqueous extracts from mushrooms or plant materials has been associated with less preparation time, higher antioxidant activity and use of water as solvent (Sharpe et al., 2021).

The total phenolic content (TPC) varied according to the mushroom strain and fruit waste substrates used (Table 2). Our findings are in agreement with the previous studies where total phenolic contents in medicinal and edible mushrooms varied depending on the growth substrate and mushroom species used (da Paz et al., 2012). The extract from the *P.ostreatus* grown on avocado peels had the highest (26.4 ± 3.8 mg GAE/g dry extract) TPC followed by extracts (24.6 ± 2.4 mg GAE/g dry extract) from *P.eryngii* grown on mango peels. Growing of *P.ostreatus* and *P.eryngii* on the watermelon rinds and banana peels respectively yielded an extract with the lowest total phenolic contents of 12.8 ± 1.6 mg GAE/g dry extract and 12.1 ± 0.8 mg GAE/g dry extract respectively. The cultivation of *P. sajor-caju* on wheat substrates yielded total phenolic content of 15.6 ± 0.8 mg GAE/g dry extract (highest) and 10.2 ± 3.2 mg GAE/g dry extract (lowest) in an extract from *P.ostreatus*. Generally, the extracts from mushrooms grown using fruit waste substrates

Table 3
Chemical composition in fruit peels and wheat straw used in this study (Suleria et al., 2020).

Substrate	TPC (mg GAE/g)	TFC (mg QE/g)	TTC (mg CE/g)
Mango peel	27.51 ± 0.63	1.75 ± 0.08	8.99 ± 0.13
Orange peel	21.31 ± 1.37	1.08 ± 0.06	8.12 ± 0.26
Pineapple peel	7.83 ± 0.35	1.47 ± 0.07	1.23 ± 0.05
Avocado peel	18.79 ± 1.46	1.24 ± 0.11	9.01 ± 0.20
Watermelon rind	2.39 ± 0.02	0.03 ± 0.01	0.02 ± 0.01
Banana peels	6.13 ± 0.25	1.32 ± 0.12	1.22 ± 0.08
Wheat straw	3.18 ± 0.14	1.39 ± 0.74	1.08 ± 0.16

TPC, Total phenolic content; TFC, total flavonoid content; TTC, total tannins content; GAE, gallic acid equivalents; QE, quercetin equivalents; CE, catechin equivalents.

comparatively had a higher yield of total phenolic contents than extracts from mushrooms grown on wheat straw substrates. Studies by Li et al. (2017) and Muthangya et al. (2014) noted similar patterns in total phenolic content in fruiting bodies in response to the growth substrate. Similarly, a study by Shetty (2004) revealed that substrate composition could potentially stimulate the biosynthesis of more phenolic compounds in mushrooms leading to variations in total phenolic content in response to the chemical composition of the growth substrates.

3.5. Antioxidant activity

The diverse range of bioactive compounds found in mushrooms is commonly linked to their functional properties. Because of their redox properties, phenolic compounds can act as reducing agents, hydrogen donors, and singlet oxygen quenchers in the human body, making them excellent candidates for antioxidant activities (Yildiz et al., 2017). Fig. 4 depicts the antioxidant activities of extracts from mushrooms grown on different substrates used in this study.

The DPPH radical scavenging activities were affected by the mushroom growth substrate. The extracts from mushrooms grown on fruit wastes were more effective at scavenging DPPH radicals than extracts from mushrooms grown on wheat straw, indicating that extracts from mushrooms grown on fruit waste substrates have higher hydrogen-donating capacities. The *P.ostreatus* grown on avocado peels had the highest DPPH radical scavenging abilities (81.2 ± 3.4%), while the *P.eryngii* grown on melon rind had the lowest (58.2 ± 2.8%), closely followed by an extract from *P. sajor-caju* grown on banana peel substrates. The 54.3% DPPH activities reported in extracts from *P. sajor-caju* grown on wheat straw were in close agreement with DPPH activities in mushroom extracts reported by Alispahi et al. (2015) and Yim et al. (2010). A significant (p-*value*<0.05) correlation ($R^2 = 0.5$) was observed between the total phenolic contents and DPPH activities in extracts from mushroom grown using different substrates. Changes in the DPPH activities resulted from changes in the levels or composition of compounds responsible for antioxidant activity in the studied mushrooms. Similarly, variations in nutritional, chemical, and antioxidant properties in edible mushrooms grown on different substrates were reported by Siwulski et al. (2019) and Yılmaz et al. (2017). Fruit wastes are a rich source of useful components such as polysaccharides, saponins, alkaloids, and other compounds (Table 3). Mushrooms, therefore, have a unique ability to absorb these chemicals from the substrates for their growth and development (Karakaya, 2004; da Paz et al., 2012). Mushrooms grown on fruit waste substrates had higher phenolic content and antioxidant activity than those grown on wheat straw substrates. Previous studies have indicated that fruit wastes are higher in chemical composition than wheat straw (Table 3). Changes in total phenolics and DPPH radical activities may be due to increased accumulation or composition of chemicals absorbed from growth substrates as reported previously (Gsecka et al., 2016).

Tshinyangu (1996) reported differences in aspartic acid, arginine, glutamic acid, leucine, lysine, and valine content in mushrooms grown on hay grass and wheat straw, confirming the ability of growth substrates to influence the chemical composition of mushrooms. Onyeka et al. (2018) reported differences in protein and fatty acid levels in *P. ostreatus* grown on various lignocellulosic substrates. Similarly, Yildiz et al. (2015) reported that the growth of mushrooms on different substrates (e.g., chestnut, black poplar, and oriental spruce) affected their total phenolic content and antioxidant activities. Likewise, the current study noted variations in the total phenolic content and antioxidant activities in mushroom grown using different substrates.

4. Conclusion

This research has shown that fruit wastes can be viable substrates for mushroom production; they also affect the chemical composition of mushrooms. Similarly, it was demonstrated that mushroom cultivation using fruit waste materials may be a novel and low-cost method of producing mushrooms rich in health-promoting compounds like antioxidants. This research may change the way mushrooms are grown by improving substrate formulation as a novel and natural strategy for improving the functional properties of edible mushrooms. Overall, findings from this study should serve as a baseline for future research to investigate new methods for improving the chemical composition of edible mushrooms for food additives and human health.

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CRediT authorship contribution statement

Jakim F. Mulaa: Conceptualization, Visualization. **George Obiero:** Supervision, Writing review & editing. **Jacob Midiwo:** Supervision, Writing review. **Ojwang D. Otieno:** Conceptualization, Methodology, Writing - original draft, Investigation, Software, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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