Coffee silverskin as a potential bio-based antioxidant for polymer materials: Brief review

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INTRODUCTION

Coffee silverskin is one of the by-products generated by the coffee industry. Although it is not the most burdensome one, because it stands only for ~4.2 wt% of coffee, it seems like an auspicious raw material for industrial processes. Coffee silverskin is characterized by a relatively low moisture content of ~5-7%, so it often does not require quite energy-consuming drying processes. The chemical composition of coffee silverskin, as well as other renewable materials, may be significantly affected by its type and origin, in this case, plant Coffea. Nevertheless, due to high fiber content, it could be considered as exciting material for the manufacturing of wood polymer composites. At the same time, it contains noticeable amounts of proteins, which may provide additional features to polymer composites. However, what is most important is the high content of antioxidants, which could noticeably enhance their lifetime by inhibition of the oxidation reactions. In the presented paper, attempts of coffee silverskin incorporation into different polymer matrices were summarized and discussed. Moreover, potential future trends in this area of research were proposed

COFFEE SILVERSKIN – GENERAL INFORMATION

The chemical composition of coffee silverskin is significantly affected by the type and origin of coffee, which can be seen in Table 1. This by-product contains mainly carbohydrates, making it relatively similar in chemical composition to the various lignocellulose materials, such as wood flour. Coffee silverskin also contains significant amounts of proteins, which during processing may also take part in Maillard reactions, generating melanoidins enhancing the antioxidant activity of the material. Moreover, this by-product contains noticeable amounts of other compounds showing antioxidant activity, such as caffeine, polyphenols, tannins, or melanoidins generated during roasting of coffee [1]. They are responsible for the excellent antioxidant activity of coffee silverskin, which, according to literature data, is in the range of 9-18 μmol TR/g, measured by DPPH assay [2]. The main compounds showing antioxidant activity present in coffee silverskin are summarized in Figure 1 [3]. Other, less popular include hyperoside, kaempferol, naringin, quercetin, or quinine.

Table 1. Composition of the coffee silverskin according to the literature data.

Compound	Content, %dry matter																			
Fibre	71.9	-	62.4	71.7	56.4	74.2	62.4	53.4	69.2	65.9	56.4	67.7	-	66.9	61.6	-	-	69.9	70.2	62.4
Insoluble	-	-	53.7	64.2	49.1	66.5	-	48.5	64.2	60.7	50.7	58.4	-	-	54.2	-	-	66.6	66.9	53.7
Soluble	-	-	8.8	7.6	7.3	10.9	-	4.9	5.0	5.2	6.3	9.3	-	-	7.4	-	-	3.3	3.3	8.8
Protein	15.5	18.7	16.2	19.0	18.8	-	18.6	18.6	19.0	18.5	19.0	17.9	12.6	15.4	17.3	14.4	-	11.9	11.8	18.6
Fat	5.8	3.8	2.2	-	2.4	3.5	2.2	2.5	2.9	3.2	3.2	2.6	-	4.6	2.1	4.9	-	2.1	2.8	2.2
Lignin	17.8	28.6	30.2	-	-	-	-	-	-	-	-	-	30.5	-	-	29.9	31.0	-	-	-
Ash	6.9	5.4	4.7	5.7	8.3	-	7.0	-	-	-	-	-	4.5	7.6	5.4	5.8	-	5.6	5.8	7.0
Cellulose	23.6	23.8	17.9	-	-	-	-	-	-	-	-	-	20.9	-	-	10.3	23.5	-	-	-
Hemicellulose	12.1	16.7	13.1	-	-	-	-	-	-	-	-	-	7.7	-	-	9.6	7.5	-	-	-
Caffeine	-	-	1.40	-	1.25	0.91	-	1.35	0.81	1.16	0.97	1.37	-	1.20	-	-	-	-	-	-
Reference	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[13]	[13]	[13]	[13]	[14]	[15]	[3]	[16]	[17]	[18]	[18]	[19]

Regarding the utilization of coffee silverskin, areas of interest include pyrolysis, manufacturing of biofuels or adsorbents, and biotechnological studies. Interesting application is the regeneration of frying oil, associated with polyphenols' high content. Due to the antioxidant activity, researchers are strongly focusing on the uses related to the food and cosmetics [4]. Coffee silverskin and its extracts show antioxidant, anti-radical, anti-inflammatory, and antimicrobial activity, but researchers also reported anti-cellulite and anti-hair loss effects [5]. It also shows antidiabetic activity and may prevent diseases related to oxidative stress, such as diabetes. These exciting features, related to the antioxidant and antimicrobial properties of coffee silverskin, also encourage using this by-product as a potential additive for polymeric materials.

COFFEE SILVERSKIN IN POLYMER TECHNOLOGY

As mentioned above, coffee silverskin show quite similar composition to materials conventionally applied as fillers for wood polymer composites. It usually contains about 60-70% of fiber, mostly insoluble (~90%). What distinguishes this by-product is the relatively high protein content (~17-18%), which may provide additional polymer composites features. They can act as plasticizers of the polymer matrix, and as mentioned earlier, take part in Maillard reactions. Moreover, due to functional groups' presence, proteins could provide additional possibilities for interfacial adhesion with polar polymer matrices. Thanks to the high content of antioxidants, silverskin may be beneficial for polymer composites' storage stability. Nevertheless, the use of this by-product in polymer technology still focuses mainly on mechanical performance without a more in-depth analysis of the additional effects. The reported effects of the coffee silverskin incorporation into polymer composites on their mechanical performance are summarized in Table 2.

Table 2. The impact of coffee silverskin on the mechanical performance of polymer composites.

Matrix	Filler content, wt%	Filler treatment	Additives	Values respectively to the neat polymer matrix, %			Ref.
				Tensile strength	Tensile modulus	Elongation at break	
PP	25	-	-	↓ 19.0	↑ 33.3	↓ 99.3	[6]
PBAT/ PHBV	10	-	-	↓ 10.7	↑ 49.7	↓ 55.6	[20]
	20			↓ 3.3	↑ 128.8	↓ 65.6	
	30			↓ 8.2	↑ 242.7	↓ 82.2	
	10			↓ 1.6	↑ 101.2	↓ 44.4	
	20			↑ 2.5	↑ 204.1	↓ 65.6	
	10	-	-	↑ 6.2	↑ 54.6	↓ 22.0	[21]
	20			↑ 10.9	↑ 171.3	↓ 44.1	
	30			↑ 4.7	↑ 233.8	↓ 69.5	
	10	Extraction of antioxidants	-	↑ 14.7	↑ 136.6	↓ 39.0	
	20			↑ 18.6	↑ 250.4	↓ 57.6	
	30			↑ 16.3	↑ 343.4	↓ 72.9	
	10	Extraction of antioxidants	Maleinized linseed oil	↑ 0.0	↑ 52.9	↓ 50.8	
	20			↑ 3.1	↑ 207.0	↓ 64.4	
	30			↑ 1.6	↑ 210.3	↓ 62.7	
	10	Silanization, APTES	-	↑ 6.2	↑ 43.8	↓ 13.6	
	20			↑ 14.0	↑ 141.0	↓ 35.6	
	30			↑ 19.4	↑ 265.0	↓ 61.0	
PLA	10	-	-	↓ 20.3	↑ 8.9	↓ 47.9	[22]
	20			↓ 22.5	↑ 22.0	↓ 46.5	
	30			↓ 50.8	↑ 32.9	↓ 78.9	
PBS	10	-	-	↓ 19.3	↑ 57.3	↓ 55.4	[22]
	20			↓ 5.6	↑ 86.4	↓ 50.0	
	30			0.0	↑ 136.3	↓ 57.1	

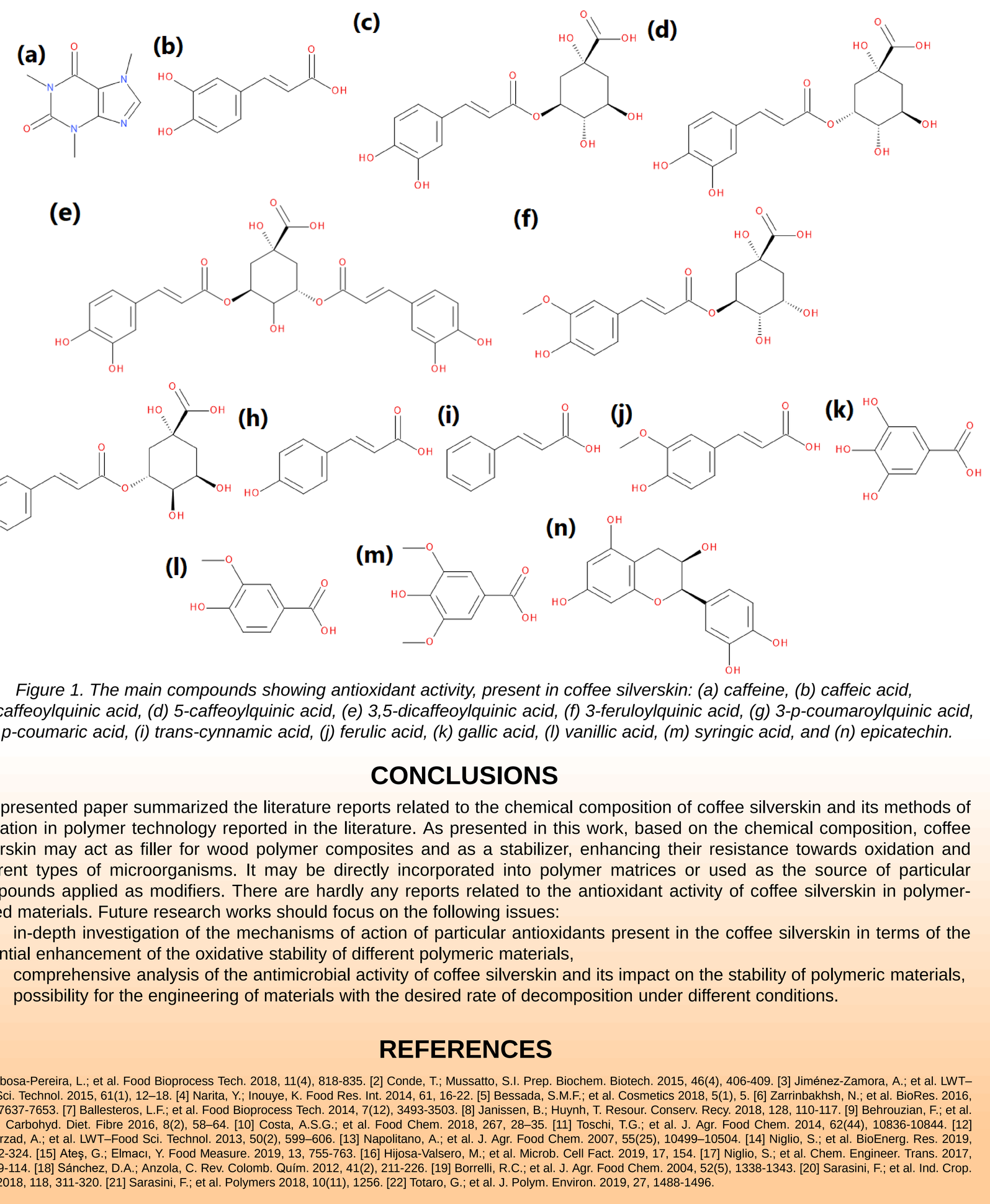

Figure 1. The main compounds showing antioxidant activity, present in coffee silverskin: (a) caffeine, (b) caffeic acid, (c) 3-caffeoylquinic acid, (d) 5-caffeoylquinic acid, (e) 3,5-dicaffeoylquinic acid, (f) 3-feruloylquinic acid, (g) 3-p-coumaroylquinic acid, (h) p-coumaric acid, (i) trans-cynnamic acid, (j) ferulic acid, (k) gallic acid, (l) vanillic acid, (m) syringic acid, and (n) epicatechin.

CONCLUSIONS

The presented paper summarized the literature reports related to the chemical composition of coffee silverskin and its methods of utilization in polymer technology reported in the literature. As presented in this work, based on the chemical composition, coffee silverskin may act as filler for wood polymer composites and as a stabilizer, enhancing their resistance towards oxidation and different types of microorganisms. It may be directly incorporated into polymer matrices or used as the source of particular compounds applied as modifiers. There are hardly any reports related to the antioxidant activity of coffee silverskin in polymer-based materials. Future research works should focus on the following issues:

- in-depth investigation of the mechanisms of action of particular antioxidants present in the coffee silverskin in terms of the potential enhancement of the oxidative stability of different polymeric materials,
- comprehensive analysis of the antimicrobial activity of coffee silverskin and its impact on the stability of polymeric materials,
- possibility for the engineering of materials with the desired rate of decomposition under different conditions.

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