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Utilization of shallot bio-waste (*Allium cepa* L. var. *aggregatum*) fractions for the production of functional cookies

https://doi.org/10.1515/ijfe-2021-0169
Received June 4, 2021; accepted November 9, 2021;
published online November 29, 2021

Abstract: Shallot harvesting and processing produce various waste streams, and the current study aims to investigate the effects of shallot bio-waste powder (SWP) substitution on different flour properties. Increased SWP to 50% substitution of stalk and petiole showed a rise in swelling capacity (43.33%) and water absorption (342.22%), and oil absorption (320.73%), respectively. Foaming capacity improved from 48.00% in control to 60.26% in 30% flower substitution and further decreases to 51.28% at 50%. Pasting properties reduced at higher SWP substitution and the highest drop in peak viscosity was observed at Stalk-50 (457.33 cP). Subsequently, developed functional cookies showed enhanced fiber, ash, total phenol, and total flavonoids with 3, 2, 7, and 5 fold, respectively. Cookies developed with higher substitution were of darker color and higher hardness and fracturability. Sensory evaluation with fuzzy analysis revealed better acceptance for stalk and petiole (10%) and peel (5%) of final cookies with elevated nutritional value.

Keywords: functional cookies; functional properties; pasting properties; shallot bio-waste utilization; value addition.

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1 Introduction

Onion is one of the highly cultivated and consumed food commodities throughout the world, and India is one of the largest producers accounting for 22.81% of global production [1]. It is an integral part of Indian cuisine, and a significant amount of produce is exported, but the perishable nature of onion hurdles long storage. Similar problems hamper the export of small onion also known as shallot, which is famous for distinguishing flavor and pungency. There is enormous export potential for shallot as it has high demand in South Asian countries. Hence, to tap the opportunity, various value-added products have been produced, thereby generating huge waste. The generated wastes of shallot mainly include flower and petiole generated during harvesting and peel and stalk during processing.

Though a sizable amount of nutrient-rich waste streams was generated from shallot, they are not emphasized for their utilization in the food matrix. Big onion peel is the only waste stream explored in terms of research towards valorization among all these waste streams. It has a high amount of insoluble and soluble polysaccharides, respectively 698 and 58 mg/g [2]. It also contains 10.6% of minerals, and the water extract contains 11,749.00 and 528.00 ppb of potassium and magnesium, respectively [3]. Onion peel is a good source of total phenols and total flavonoids and possesses antioxidant activity [4], thrice as that of fresh onion and highly contributed by Quercetin [5]. However, these studies are mainly focusing on the valorization of onion peel obtained from big onion varieties.

Attempts have been made to utilize the onion waste as an absorbent [6], source of polysaccharides and sugars [7], source of quercetin [8], as a substrate for vinegar production [9], and as a packaging ingredient [10]. A couple of studies reported the addition of only onion peel in foods like bread [11, 12] and pasta [13] and not considering other waste fractions. But the addition was considered based on antioxidant activity, which enables the addition of a significantly less quantity of onion waste. Inconsequent, low quantity addition does not emphasize the utilization of fibers and minerals of which shallot waste (SW) is a good source [11–13].

Moreover, substitution plays a vital role in value addition. Nevertheless, the degree of substitution relies on the change in functional and pasting properties of flour and nutritional augmentation of developed value-added products. Consequently, the current study is undertaken to analyze the effect of incorporating various shallot bio-waste powders (SWP) *viz.* peel, stalk, flower, and petiole on functional and pasting properties of refined wheat flour (RWF) and further the properties of functional cookies developed with these flour mix.

2 Materials and methods

2.1 Sample collection

The waste streams from cured shallot onion of CO-2 variety were collected from a local industry of Tamil Nadu, India. The collected samples were cleaned manually to remove the dockages. Ingredients used for cookie preparation were purchased from the local market. The chemicals used were of analytical grade and procured from Hi-Media Laboratories Pvt. Ltd. (Himedia, Nashik, India).

2.2 Preparation of flour mix

The collected SW were dried separately using a tray dryer at 50 °C for 12 h, pulverized at room temperature, and sieved through a 210 µm sieve. The shallot bio-waste powders (SWP) *viz.* peel powder (P), stalk powder (S), flower powder (F), and petiole powder (PT) were then substituted with RWF from 10 to 50%, as represented in Table S1.

2.3 Functional properties

The functional properties of SWP and flour mixes were measured in terms of swelling capacity (SC) [14], water absorption capacity (WAC), oil absorption capacity (OAC), water solubility index (WSI) [15], foaming capacity (FC) and foaming stability (FS), emulsion capacity (EC) and emulsion stability (ES) [16], and least gelation concentration (LGC) [17] with slight modification and detailed method is described in the Supplementary Material.

2.4 Flow properties

Bulk density (BD; ρ_B) and tapped density (TD; ρ_T), and flow properties include the Hausner ratio (HR) and Carr's index (CI) for SWP and flour mix were determined with the standard method described by Lavanya *et al.* [18].

2.5 Pasting properties

The rheological properties of SWP and flour mix were measured using Rapid Visco Analyzer (MCR-302, Anton-Paar, Graz, Austria) [19]. The sample preparation and detailed program for analysis are given in Supplementary Material.

2.6 Development of cookies

The cookies were developed with the standard procedure reported by Theagarajan *et al.* [20] with slight modification.

2.6.1 Quality analysis of cookies

2.6.1.1 Physical properties of developed cookies: The developed cookies were analyzed for the physical properties such as spread ratio, color, and texture with a standard method described in the Supplementary Material.

2.6.1.2 Composition of developed cookies: The proximate composition, mainly protein, fiber, and ash content of cookies were analyzed using the standard method described by Theagarajan *et al.* [20].

2.6.1.3 Phytochemical properties of cookies: The powdered samples were extracted with methanol (1:10 m/v) and analyzed for total phenol and total flavonoid content with standard methods described by Wang, Vanga, and Raghavan [21]. The confirmation of phytochemicals was done using phytochemical screening with methanolic extract of SWP using LC-MS/MS (Shimadzu Corporation, Kyoto, Japan).

2.6.1.4 Fuzzy logic analysis of sensory attributes: Sensory perception of shallot waste incorporated cookies was evaluated by thirty semi-trained panel members comprising research scholars and staff of the institute. The assessment was done with a fuzzy logic technique [22, 23].

2.7 Statistical analysis

All analysis was performed in triplicates, and the results were represented as mean ± standard error. One-way analysis of variance and the Tuckey test was performed to evaluate the significant difference ($p \le 0.05$) between the means of the analyzed parameters using MINITAB 17.0 as a statistical tool.

3 Result and discussion

3.1 Functional properties

The functional properties of the flour mix developed by substituting SWP were analyzed and represented in Figure 1 and the findings are discussed in the following section.

3.1.1 Water absorption capacity (WAC)

Substitution of RWF with SWP showed direct relation with WAC. Maximum WAC was observed in PT-50, *i.e.*, 343.22 with 102.78% deviation compared to the control sample. The results revealed that 20% substitution was on par with the control sample. Phenolic compounds in waste streams enhance the hydrophilic interactions of starch and fiber, contributing to the higher WAC of the flour mixes [24]. Hydrophilicity represents the ability of a molecule to bind

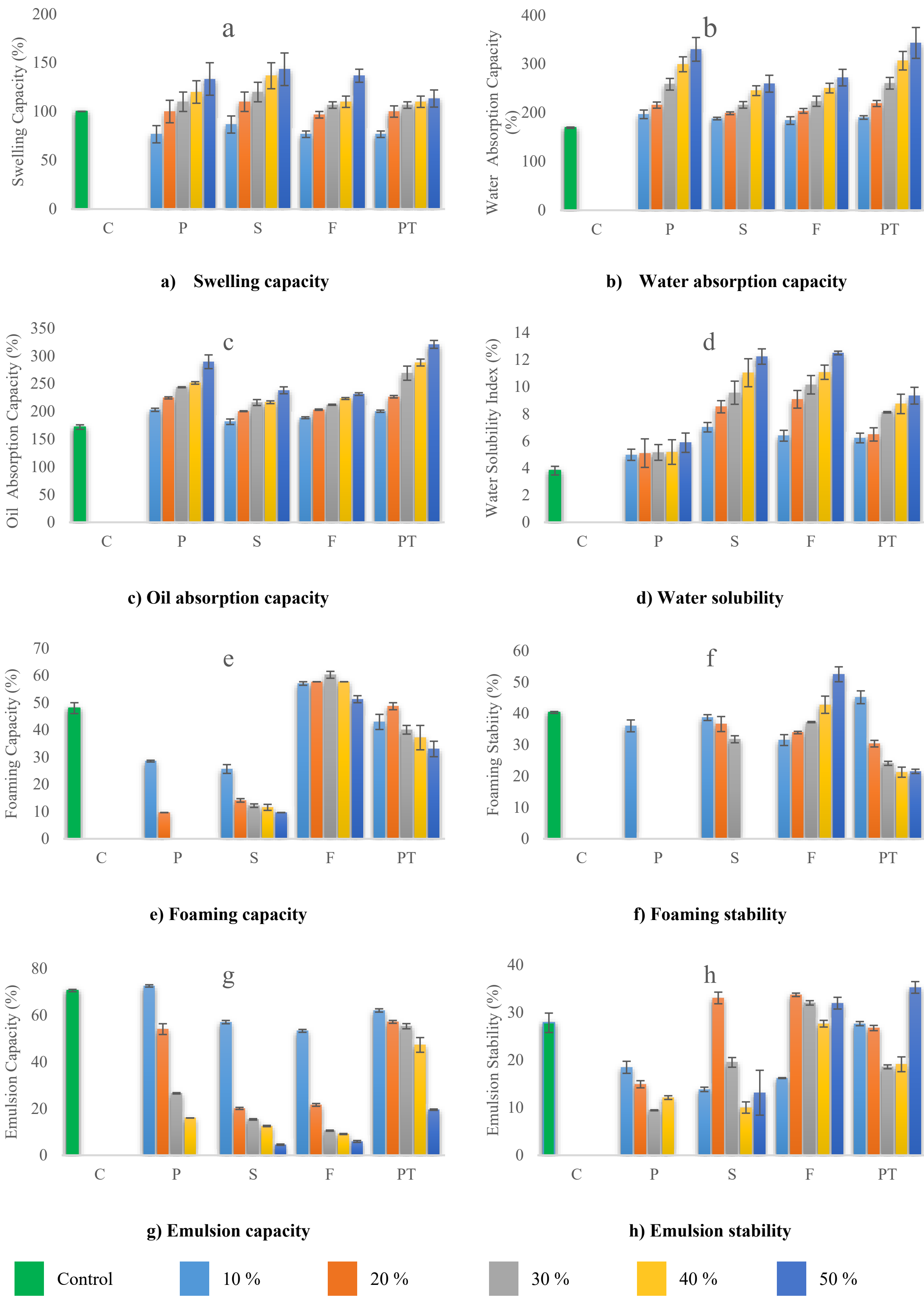

Figure 1: Functional properties of flour mix substituted with selected shallot waste.

the water with hydrogen bonding. The major ingredients such as fibers and starch enclose the polyphenolic compounds. The presence of polyphenolic compounds increases the hydrophilic sites for water binding, which in response increases the water absorption capacity of the flour [25].

3.1.2 Swelling capacity (SC)

An increase in substitution of SWP has increased SC. The maximum deviation of 43.33% in SC was observed in S-50 compared to the control sample. Whereas PT-50 showed the least deviation of 13.33% only considering 50% substitution. However, the change in SC was non-significant. The absorption of water increases the volume of starch [16] and fibers [24]. Flour with higher swelling capacity can give bulking action to food and hence can be used in bakery products. Moreover, the solubility of the fiber may also affect the swelling capacity; hence, the petiole showed a slight divergence in SC. The starch and fibers in the flour entrap the water available prior to and during the gelatinization process. Due to the entrapment of water, intramolecular space between the starch and fiber structure increases. This causes swelling in the flour added with shallot waste streams as it contains a higher amount of fibers in it [16, 24].

3.1.3 Oil absorption capacity (OAC)

The OAC showed gradual elevation concerning an increase in substitution with SWP. The highest OAC of 320.73% was observed for PT-50. The values for degree of deviation from control to 50% substitution of peel, stalk, flower, and petiole were 68.62, 38.64, 34.64, and 86.82%, respectively. Fibers are known to possess the capacity to absorb oil which may play an important role in increased OAC of the flour mix. Moreover, constituents such as chlorophyll, carotenoids, and pheophytin are proven to have lipophilic nature, which may also contribute to increased OAC [26].

3.1.4 Water solubility index (WSI)

Substitutions for peel were on par with the control sample as the maximum degree of deviation (53.93%) was observed for P-50 considering peel substitution. However, substitution with stalk, flower, and petiole was significant and showed a higher degree of deviation (84.21, 67.28, and 63.09%, respectively) at 10% substitution itself, which further increases gradually till 50% substitution. WSI represents the presence of water-soluble constituents, which may be sugars and soluble fibers. Increased WSI represents the presence of water binding sites such as phenolic, and increases its accessibility with respect to an increase in SWP [16].

3.1.5 Foaming capacity (FC) and stability (FS)

Except for shallot flower, FC showed a significant decrease ($p \leq 0.05$) with respect to increase in the substitution with shallot waste powder compared to control. The least FC was observed in flour mix with substitution of the peel as there was no foam observed in P-30 and further substitutions. Unlike other waste streams, flower substitution initially showed an increase in FC up to F-30 and further declined. The decrease in FS was observed with an increase in shallot waste substitution except for flowers. The FS for flowers increased from 31.49% (F-10) to 52.47% (F-50), which accounts 30.20% increase in the control sample. The air gets entrapped in the flexible protein structures and establishes foam. The substitution of RWF with shallot waste decreases the relative amount of proteins and increases the fiber content except flower, as it contains more protein than any other shallot waste. These fibers possibly rupture protein structure in the bubble wall, causing a faster coalescence rate, forming unstable foam reducing FC and FS [27]. Moreover, the presence of soluble fiber may also play a role in FC and FS for shallot stalk and petiole [28].

3.1.6 Emulsion capacity (EC) and stability (ES)

An increase in the substitution of shallot waste reduces the EC of the flour mix. The controlled sample showed 70.5% of emulsion capacity, and the lowest was observed in flour mix with 50% substitution of shallot peel powder. Like EC, ES also showed decreasing trend with increased substitution of SWP. The hydrophilic and lipophilic compounds present in the flour mix form the emulsion. The fibers present in the flour mix substituted with shallot waste tend to absorb the water and might increase the density gradient. This change in density gradient will cause settlement of solids reducing the EC and ES.

3.1.7 Least gelation concentration

The least gelation concentration is represented in Table 1. Shallot peel and flower showed gelation concentration at 6% for all substitution. The stalk and petiole showed similar results till 30% substitution as the flour mix formed gel at 6% only. But, the flour mix with 40 and 50% stalk and petiole substitution form gel at 4% itself. The presence of higher soluble fibers within the inner mucilage of stalk and petiole could be the reason for gelation at lower concentrations [28]. Shallot stalk and petiole are internally lined

Table 1: Functional properties of flour mix substituted with selected shallot waste.

Substitution	Peel	Stalk	Flower	Petiole
C	8	8	8	8
10	6	6	6	6
20	6	6	6	6
30	6	6	6	6
40	6	4	6	4
50	6	4	6	4

with a thin layer of mucilage which mostly contain soluble dietary fibers. These soluble dietary fibers will bind other constituents and help the formation of the gel during the heating. This might be the reason for the formation of gel at lower concentration in flour mix substituted with shallot stalk and petiole [10, 29].

3.2 Flow properties

BD and TD of flour mix showed inverse proportion with the increase in flour substitution with all SWP. This could be due to the lower density of fibers present in SWP [30]. The maximum significant decrease ($p \leq 0.05$) in BD and TD was observed in PT-50, accounting for 58.11 and 45.70%, respectively. Values of HR and CI for the control sample were 1.300 and 23.08, respectively, showing it is flowable. As HR and CI are mainly dependent on the BD and TD of the sample [31], the same could be the reason for the decline in flowability of flour mix with increased SWP substitution. The detailed results are given in Supplementary Material (Table S4a and S4b).

3.3 Pasting properties

The pasting properties such as peak viscosity, holding strength, breakdown strength, final viscosity, and setback viscosity (trough) showed a gradual declining trend with an increase in the substitution with shallot waste. The highest decline of 83.10, 85.55, 80.71, 87.47, and 89.23% was observed in peak viscosity, holding strength, breakdown strength, final viscosity, and setback viscosity (trough), respectively in S-50. The findings for the change in pasting properties are represented in Figure 2. The change in pasting properties is mainly dependent upon starch content and its modification. Substitution of the shallot waste decreases the relative concentration of starch. The fibers interfere with water availability and bonding of starch resulting reduction in peak viscosity and increasing pasting temperature. Likewise, rearrangement of starch during retrogradation is hampered by insoluble fibers reducing setback and final

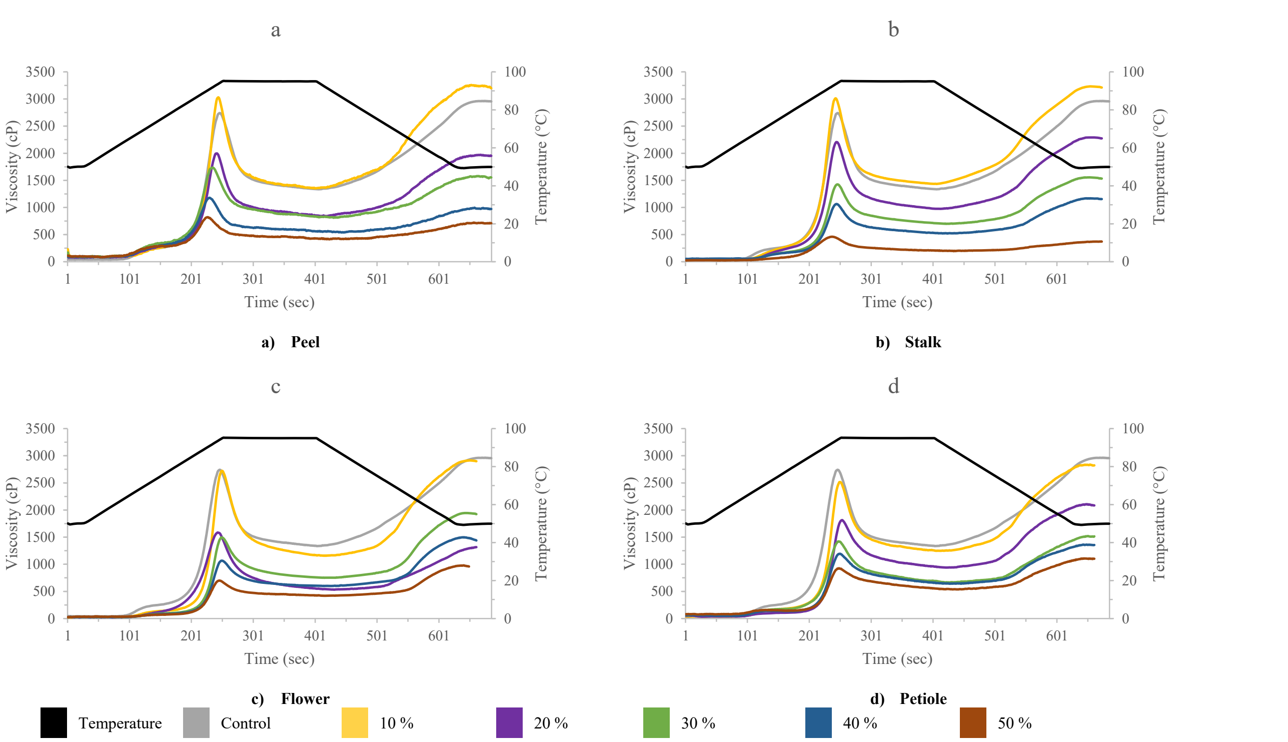

Figure 2: Pasting properties of flour mix substituted with selected shallot waste.

viscosity [17]. Similar trends were observed when hydrocolloids were added to colocasia starch.

3.4 Quality evaluation of cookies

The cookies were developed from flour mix substituted with various shallot waste powder. The developed cookies were analyzed for various physicochemical and phytochemical properties.

3.4.1 Spread ratio

The spread ratio of the cookies was observed to decrease with increased SWP substitution. These results can be coincided with the decrease in flow properties and increase in functional properties such as water absorption and oil absorption. This fiber gives dense dough resulting in a lower spread ratio [32].

3.4.2 Color

The color approaches dark with increased shallot waste substitution in RWF. The controlled sample demonstrated the highest L^* value of 80.05 ± 0.63, which further decline, and the lowest of it was observed in sample F-50 with 29.77 ± 0.17 value. This color shift can be related to a lower L^* value. At the same time, cookies developed by substitutions of shallot peel showed a significant deviation a^* value. Whereas for other substitutions of stalk, flower, and petiole, a^* and b^* showed a reducing trend and were found significantly different ($p \le 0.05$) from the control sample (color values of SWP given in Table S6). This in turn increases the ΔE value (reported in Table 2). The highest significant deviation in ΔE value was observed in F-50. Similar results were observed by Ahmad *et al.* and Theagrajan *et al.* for cookies development with the addition of green tea powder and grape skin powder, respectively [16, 20].

3.4.3 Hardness and fracturability

The hardness and fracturability of the product show an increasing trend with the substitution of shallot waste. These results can be correlated to increased functional properties such as water absorption of the flour mix with higher waste substitution giving a hard texture to the cookies. At the same time, these fibers interfere with the structure of proteins forming the compact product resulting in increased hardness [33]. Kaur *et al.* reported that flour with higher water and oil absorption gives cookies with higher hardness and fracturability. Moreover, the lower particle size of substituted fiber also affects product quality significantly [32].

3.4.4 Water activity

The cookies developed with a lower degree of substitution showed lower water activity than the control sample, and further substitutions showed increased water activity. The results are represented in Table 3. Similar results were observed by Theagarajan *et al.* [20]. The minimum a_w required for microbial growth is 0.61 [34]. However, the water activity of developed cookies was well within the safe limit for safe storage. Even higher WAC can be a contributor towards higher hardness and increased a_w.

3.4.5 Moisture content

The functional cookies developed with flour mix with higher SWP substitution were observed with higher moisture content in comparison with the RWF cookies. The highest increase in the moisture content was observed with the functional cookies prepared with the P-50 sample with around 63% of deviation. These results showed close relation with the higher water absorption capacity of the flour mixes. At the time of dough preparation, fibers in the SWP absorb higher moisture as the water of mixing. The complete removal of absorbed water at the time of baking does not occur resulting in higher moisture content in the finished cookies [20].

3.4.6 Protein

Cookies showed decreased protein content with an increase in the degree of shallot waste substitution except for shallot flowers. F-10 showed a nearly 2% increase in protein compared with the control sample, which gradually increased till F-50 with the highest deviation of 54.46%. ANOVA reveals significance ($p \le 0.05$) for change in protein content of shallot waste powder substituted cookies. The presence of the increased amount of fibers and minerals can be correlated with these results. Likewise, a higher amount of protein in cookies substituted with shallot flower was observed [29]. Higher protein content can be correlated with the higher foaming capacity and stability of flour with shallot flower substitution [16].

3.4.7 Fiber

The fiber content of the developed cookies showed a significant increase with the increase in the degree of shallot waste powder substitution. There is an almost three-fold

Table 2: Physical properties of developed functional cookies with SWP substitution.

Substitution	Spread ratio	L^*	a^*	b^*	ΔE	Hardness (gF)	Fracturability (gF)
C	5.38 ± 0.05^{a}	80.05 ± 0.63^{a}	3.27 ± 0.21^{d}	29.21 ± 0.36^{a}		966.26 ± 27.24^{e}	617.43 ± 77.61^{b}
P-10	5.19 ± 0.05^{ab}	50.32 ± 1.16^{b}	8.89 ± 0.09^{c}	19.21 ± 0.50^{b}	31.90 ± 0.90^{c}	1047.13 ± 47.90^{de}	853.61 ± 117.16^{b}
P-20	5.09 ± 0.17^{ab}	43.61 ± 0.74^{c}	9.24 ± 0.28^{c}	17.04 ± 0.30^{c}	38.91 ± 1.21^{b}	1384.02 ± 51.98^{cd}	978.15 ± 67.74^{b}
P-30	4.90 ± 0.05^{ab}	38.57 ± 0.25^{d}	9.93 ± 0.11^{bc}	15.38 ± 0.08^{d}	44.24 ± 0.60^{a}	1558.60 ± 86.17^{c}	1004.09 ± 46.57^{b}
P-40	4.81 ± 0.09^{b}	35.81 ± 0.49^{d}	10.53 ± 0.04^{ab}	12.96 ± 0.27^{e}	47.70 ± 0.45^{a}	2242.79 ± 108.46^{b}	1627.16 ± 145.29^{a}
P-50	4.71 ± 0.14^{b}	35.29 ± 0.58^{d}	11.46 ± 0.47^{a}	12.90 ± 0.36^{e}	48.37 ± 0.39^{a}	2776.15 ± 141.45^{a}	2037.55 ± 209.55^{a}
C	5.38 ± 0.05^{a}	80.05 ± 0.63^{a}	3.23 ± 0.21^{c}	29.21 ± 0.36^{ab}		966.26 ± 27.24^{b}	617.43 ± 77.61^{d}
S-10	5.37 ± 0.04^{a}	55.32 ± 0.32^{b}	10.69 ± 0.11^{b}	34.57 ± 0.24^{a}	26.39 ± 0.43^{d}	997.80 ± 33.39^{b}	728.63 ± 138.59^{cd}
S-20	5.13 ± 0.19^{ab}	50.37 ± 0.28^{c}	10.79 ± 0.03^{b}	32.84 ± 0.24^{ab}	30.85 ± 0.44^{c}	1034.45 ± 125.66^{b}	783.28 ± 54.81^{cd}
S-30	4.67 ± 0.15^{bc}	43.60 ± 0.12^{d}	10.81 ± 0.14^{a}	30.36 ± 0.24^{ab}	37.53 ± 0.57^{b}	1337.18 ± 73.55^{b}	1122.54 ± 56.71^{bc}
S-40	4.56 ± 0.11^{c}	39.10 ± 0.19^{e}	11.00 ± 0.05^{b}	27.57 ± 0.05^{bc}	41.72 ± 0.71^{a}	1807.32 ± 173.52^{a}	1459.40 ± 141.62^{ab}
S-50	4.44 ± 0.06^{c}	37.58 ± 0.32^{e}	12.02 ± 0.01^{b}	22.30 ± 3.37^{c}	43.99 ± 0.87^{a}	2030.93 ± 127.44^{a}	1604.24 ± 78.51^{a}
C	5.38 ± 0.05^{a}	80.05 ± 0.63^{a}	3.23 ± 0.21^{d}	29.21 ± 0.36^{a}		966.26 ± 27.24^{c}	617.43 ± 77.61^{b}
F-10	4.96 ± 0.18^{ab}	45.49 ± 0.11^{b}	7.92 ± 0.04^{a}	26.30 ± 0.04^{b}	35.01 ± 0.56^{d}	1168.13 ± 65.29^{bc}	1030.45 ± 72.43^{a}
F-20	4.55 ± 0.16^{bc}	38.40 ± 0.17^{c}	7.37 ± 0.02^{b}	21.31 ± 0.29^{c}	42.58 ± 0.4^{c}	1360.48 ± 57.02^{ab}	1061.84 ± 125.09^{a}
F-30	4.33 ± 0.13^{c}	34.30 ± 0.30^{d}	7.23 ± 0.03^{b}	18.53 ± 0.09^{d}	47.17 ± 0.46^{b}	1417.06 ± 42.64^{ab}	1231.20 ± 107.85^{a}
F-40	4.18 ± 0.04^{c}	30.14 ± 0.08^{e}	7.11 ± 0.05^{b}	14.95 ± 0.08^{e}	52.07 ± 0.57^{a}	1461.06 ± 67.72^{a}	1271.08 ± 92.04^{a}
F-50	4.13 ± 0.12^{c}	29.77 ± 0.17^{e}	6.58 ± 0.08^{c}	13.91 ± 0.12^{f}	52.67 ± 0.59^{a}	1528.86 ± 93.42^{a}	1334.44 ± 91.87^{a}
C	5.38 ± 0.05^{a}	80.05 ± 0.63^{a}	3.23 ± 0.21^{d}	29.21 ± 0.36^{a}		966.26 ± 27.24^{a}	617.43 ± 77.61^{d}
PT-10	4.96 ± 0.29^{a}	48.83 ± 0.27^{b}	10.50 ± 0.04^{a}	29.23 ± 0.13^{a}	32.04 ± 0.40^{c}	1247.80 ± 79.55^{a}	939.57 ± 96.25^{cd}
PT-20	4.78 ± 0.13^{a}	43.23 ± 0.07^{c}	10.39 ± 0.03^{a}	26.24 ± 0.06^{b}	37.65 ± 0.58^{b}	1279.77 ± 60.60^{a}	1169.94 ± 73.26^{bc}
PT-30	4.04 ± 0.14^{b}	42.05 ± 0.03^{cd}	10.20 ± 0.03^{ab}	25.69 ± 0.04^{b}	38.80 ± 0.66^{b}	1429.25 ± 47.03^{a}	1184.78 ± 145.43^{bc}
PT-40	3.74 ± 0.04^{b}	41.30 ± 0.31^{d}	9.78 ± 0.06^{bc}	25.49 ± 0.35^{b}	39.49 ± 0.40^{ab}	1629.34 ± 51.31^{a}	1451.20 ± 77.28^{ab}
PT-50	3.66 ± 0.12^{b}	39.49 ± 0.03^{e}	9.72 ± 0.08^{c}	24.28 ± 0.01^{c}	41.38 ± 0.61^{a}	1882.17 ± 114.70^{a}	1744.80 ± 129.21^{a}

P, peel; S, stalk; F, flower; PT, petiole. Values sharing different letters 'a-f' in table notify the statistical significance among the treatments ($p \leq 0.05$).

Table 3: Composition of developed functional cookies with SWP substitution.

Substitution	Moisture (%)	Protein (%)	Fiber (%)	Fat (%)	Ash (%)	Carbohydrate (%)	Water activity	Phenol (mg/g)	Flavonoid (μg/g)
C	4.33 ± 0.05^{f}	6.77 ± 0.05^{a}	0.40 ± 0.001^{f}	24.51 ± 0.15^{a}	0.47 ± 0.10^{e}	63.52 ± 0.13^{a}	0.380 ± 0.012^{b}	2.77 ± 0.22^{f}	59.58 ± 2.20^{f}
P-10	4.65 ± 0.18^{e}	6.39 ± 0.18^{a}	0.93 ± 0.002^{e}	24.21 ± 0.37^{a}	0.87 ± 0.09^{d}	62.87 ± 0.07^{b}	0.365 ± 0.005^{b}	30.27 ± 0.03^{e}	291.25 ± 1.44^{e}
P-20	4.97 ± 0.09^{d}	6.27 ± 0.09^{ab}	2.29 ± 0.005^{d}	24.29 ± 0.23^{a}	1.37 ± 0.01^{c}	60.82 ± 0.06^{c}	0.350 ± 0.006^{b}	60.96 ± 0.03^{d}	387.08 ± 1.67^{d}
P-30	5.49 ± 0.08^{c}	5.77 ± 0.08^{bc}	2.79 ± 0.006^{c}	25.02 ± 0.08^{a}	1.58 ± 0.04^{c}	59.31 ± 0.07^{d}	0.343 ± 0.003^{b}	74.01 ± 0.06^{c}	438.75 ± 3.82^{c}
P-40	6.30 ± 0.03^{b}	5.46 ± 0.03^{cd}	3.42 ± 0.007^{b}	24.51 ± 0.36^{a}	1.94 ± 0.09^{b}	58.29 ± 0.11^{e}	0.352 ± 0.015^{b}	84.14 ± 0.12^{b}	516.25 ± 1.44^{b}
P-50	7.03 ± 0.17^{a}	5.13 ± 0.17^{d}	3.80 ± 0.007^{a}	24.81 ± 2.40^{a}	2.79 ± 0.07^{a}	56.41 ± 0.10^{f}	0.437 ± 0.009^{a}	98.81 ± 0.08^{a}	678.75 ± 5.20^{a}
C	4.33 ± 0.05^{d}	6.77 ± 0.05^{a}	0.40 ± 0.001^{f}	24.51 ± 0.15^{a}	0.47 ± 0.10^{e}	63.52 ± 0.13^{a}	0.380 ± 0.012^{a}	2.77 ± 0.22^{d}	59.58 ± 2.20^{e}
S-10	4.45 ± 0.14^{d}	6.52 ± 0.14^{a}	1.13 ± 0.002^{e}	24.10 ± 2.40^{a}	1.06 ± 0.06^{d}	62.76 ± 0.20^{b}	0.383 ± 0.015^{a}	6.94 ± 0.86^{c}	269.58 ± 2.20^{d}
S-20	4.61 ± 0.05^{cd}	5.95 ± 0.05^{b}	1.96 ± 0.004^{d}	24.75 ± 0.15^{a}	1.34 ± 0.04^{cd}	61.30 ± 0.09^{c}	0.381 ± 0.012^{b}	14.45 ± 0.05^{b}	311.25 ± 3.82^{c}
S-30	4.89 ± 0.21^{bc}	5.25 ± 0.21	2.49 ± 0.005^{c}	24.03 ± 0.06^{a}	1.43 ± 0.04^{c}	61.87 ± 0.19^{c}	0.407 ± 0.003^{c}	18.40 ± 0.03^{a}	328.75 ± 2.50^{b}
S-40	5.03 ± 0.05^{b}	4.60 ± 0.05^{d}	3.06 ± 0.006^{b}	24.55 ± 0.18^{a}	2.61 ± 0.06^{b}	60.21 ± 0.13^{d}	0.363 ± 0.003^{d}	18.84 ± 0.05^{a}	384.58 ± 4.41^{b}
S-50	5.94 ± 0.07^{a}	4.15 ± 0.07^{d}	4.59 ± 0.009^{a}	24.60 ± 0.10^{a}	3.81 ± 0.08^{a}	56.98 ± 0.1^{e}	0.425 ± 0.006^{d}	18.90 ± 0.03^{a}	398.75 ± 4.33^{a}
C	4.33 ± 0.05^{d}	6.77 ± 0.05^{e}	0.40 ± 0.001^{f}	24.51 ± 0.10^{e}	0.47 ± 0.10^{e}	63.52 ± 0.13^{a}	0.380 ± 0.012^{ab}	2.77 ± 0.22^{f}	59.58 ± 2.20^{e}
F-10	4.34 ± 0.02^{d}	6.90 ± 0.02^{e}	0.96 ± 0.002^{e}	25.91 ± 0.06^{d}	0.70 ± 0.04^{de}	61.23 ± 0.09^{b}	0.303 ± 0.020^{c}	19.53 ± 0.03^{e}	357.08 ± 3.63^{d}
F-20	4.41 ± 0.01^{cd}	8.18 ± 0.01^{d}	1.96 ± 0.004^{d}	26.96 ± 0.18^{c}	0.98 ± 0.02^{cd}	57.53 ± 0.0^{c}	0.338 ± 0.014^{abc}	29.34 ± 0.03^{d}	395.42 ± 3.63^{c}
F-30	4.50 ± 0.01^{bc}	8.60 ± 0.01^{c}	2.26 ± 0.004^{c}	29.13 ± 0.10^{b}	1.22 ± 0.13^{bc}	54.20 ± 0.17^{d}	0.330 ± 0.010^{bc}	30.90 ± 0.05^{c}	402.08 ± 6.01^{c}
F-40	4.57 ± 0.08^{b}	9.20 ± 0.08^{b}	3.26 ± 0.006^{b}	30.14 ± 0.02^{a}	1.58 ± 0.05^{ab}	51.31 ± 0.13^{e}	0.404 ± 0.002^{a}	36.75 ± 0.03^{b}	425.42 ± 4.17^{b}
F-50	4.99 ± 0.07^{a}	10.45 ± 0.07^{a}	3.99 ± 0.008^{a}	30.43 ± 0.11^{a}	1.88 ± 0.07^{a}	48.19 ± 0.18^{f}	0.361 ± 0.019^{abc}	47.06 ± 0.05^{a}	449.58 ± 2.20^{a}
C	4.33 ± 0.05^{f}	6.77 ± 0.05^{a}	0.40 ± 0.001^{f}	24.51 ± 0.15^{ab}	0.47 ± 0.10^{c}	63.52 ± 0.13^{a}	0.380 ± 0.012^{ab}	2.77 ± 0.22^{f}	59.58 ± 2.20^{e}
PT-10	4.47 ± 0.03^{e}	6.51 ± 0.03^{b}	1.46 ± 0.003^{e}	24.51 ± 0.36^{ab}	0.62 ± 0.08^{c}	62.44 ± 0.1^{b}	0.360 ± 0.026^{b}	20.15 ± 0.09^{e}	169.58 ± 2.20^{d}
PT-20	4.63 ± 0.02^{d}	6.41 ± 0.02^{b}	2.69 ± 0.005^{d}	25.02 ± 0.33^{a}	0.78 ± 0.11^{bc}	60.47 ± 0.10^{c}	0.401 ± 0.021^{ab}	22.30 ± 0.05^{d}	234.58 ± 5.83^{c}
PT-30	5.00 ± 0.09^{c}	6.39 ± 0.09^{b}	3.82 ± 0.007^{c}	24.81 ± 0.13^{ab}	1.10 ± 0.06^{b}	59.01 ± 0.17^{d}	0.419 ± 0.001^{ab}	25.66 ± 0.16^{c}	357.92 ± 4.41^{b}
PT-40	5.41 ± 0.01^{b}	6.34 ± 0.01^{b}	4.35 ± 0.009^{b}	24.19 ± 0.23^{b}	1.15 ± 0.14^{ab}	58.50 ± 0.15^{d}	0.416 ± 0.001^{ab}	30.18 ± 0.14^{b}	361.25 ± 5.00^{a}
PT-50	5.85 ± 0.03^{a}	6.04 ± 0.01^{a}	5.62 ± 0.012^{a}	24.68 ± 0.16^{ab}	1.58 ± 0.04^{a}	56.22 ± 0.0^{e}	0.443 ± 0.004^{a}	32.33 ± 0.08^{a}	387.92 ± 6.01^{a}

P, peel; S, stalk; F, flower; PT, petiole. Values sharing different letters 'a-f' in table notify the statistical significance among the treatments ($p \leq 0.05$).

increase in the fiber content even at the lowest degree of substitution. Cookies developed with flour mix P-10, S-10, F-10, and PT-10 showed 133, 183, 141 and 266% increase in fiber content respectively. The highest increase in the fiber content was observed in PT-50. In a recent study, Bhosale *et al.* demonstrated the detailed composition of shallot waste. The study revealed the abundance of fibers, minerals, and other phytochemicals, and only shallot flower was found rich in protein [29].

3.4.8 Fat

The fat content of the developed functional cookies with the substitution of SWP showed a decreasing trend. However, the cookies developed with the shallot flower substitution were found to increase the fat content. F-10 cookies sample was found to curb the fat content of 25.91 ± 0.06% which gradually increases to 30.43 ± 0.11% in F-50 cookies. Unlike cookies samples developed with flour mix by substituting flower powder, the change in fat content was statistically insignificant. The major amount of the fat in developed functional cookies was added externally in form of whipped cream along with sugar. The flour mixes and other ingredients used in cookies preparation do not share any significant amount of fat in preparation. However, the shallot flower was already found to be a good source of fat and may have come up with a considerable amount of fat [29, 35]. This may result in the elevated fat content in cookies developed with shallot flower substitution.

3.4.9 Ash

Ash content followed an increasing trend with an increase in shallot waste substitution. An increase in ash content was significant ($p \leq 0.05$) at all levels of substitution. The lowest substitution of 10% showed a two-fold increase in ash content of developed cookies. The highest ash content was observed for S-50, which showed an almost eight-fold increase. A couple of studies has reported higher mineral content in onion peel, and the same can be considered for shallot waste too for higher ash content [29, 36].

3.4.10 Carbohydrate

The carbohydrate content of the developed functional cookies was analyzed by differentiating method and the results are depicted demonstrated in Table 3. The highest carbs were observed in cookies developed with RWF. The progression in the substitution with SWP results in a decrease in the carbohydrate content. The highest deviation of around 24% was observed in the sample developed with the F-50 flour mix. Whereas, the lowest decline of 11.49% when considering the highest degree of substitution, was observed in PT-50. The carbohydrate content of the developed functional cookies is mainly dependent on the relative concentration of other constituents. The results discussed in the previous section demonstrated the increase in other constituents which may be the reason for the decline in carbohydrates. The functional cookies developed with the flower substitution showed a greater increase in protein and fat content, this might be the reason for an even greater dip in carbohydrate content in developed functional cookies [20, 29].

3.4.11 Total phenol content

The lowest total phenol content was observed in the control sample, as low as 2.766 mg/mL. A major increase in the total phenol was observed in the cookies substituted with shallot peel. The highest was observed in P-50, followed by the flower and petiole, and lowest in samples substituted with stalk. Though the increase in the phenol is lower in the stalk, S-10 showed a 150.94% increase compared to the control sample. Similarly, cookies developed with P-10, F-10, and PT-10 showed a nearly 11-fold, 7-fold, and 7-fold increase, respectively, in the total phenol content [10, 29].

3.4.12 Total flavonoids

Similar to total phenols, total flavonoids also showed an increasing trend with increasing substitution with shallot waste in developed cookies. An increase in total flavonoid content was found significant ($p \leq 0.05$) at all substitution levels compared to control. The highest increase was observed in cookies developed with peel powder among wastes, and 50% substitution was observed to have the highest increase within the waste streams. The cookies, even with the least substitution of 10%, showed a significant increase ($p \leq 0.05$) in total flavonoids (P-10 5.8 fold, S-10 2.8 fold, F-10 5.99 fold, and PT-10 4 fold). The reports are available, giving the superiority of shallot peel in terms of total phenol and flavonoid content and higher phytochemicals (results depicted in Table S7 in Supplementary Material) which may be the reason for high phenol and flavonoid content [10, 29].

3.4.13 Phytochemical analysis

Several potential phytochemicals were identified over the range of methanolic extract of shallot bio-waste powder. The analyzed compounds were found to have different

Table 4: Potential phytochemical identified for selected shallot bio-waste with their biological activity.

S. no	Compounds	Formula	RI	Theoretical (*m*/*z*)	Observed (*m*/*z*)
Peel					
1	Norfenefrine	$C_8H_{11}NO_2$	8.09	153.07	152.85
2	Psoralen	$C_{11}H_6O_3$	5.51	186.03	188.85
3	Benzoic acid, 2,4,6-trinitro-	$C_7H_3N_3O_8$	9.55	256.99	256.95
4	Dihydrobiochanin A	$C_{16}H_{14}O_5$	5.20	286.08	287.00
5	Sativanone	$C_{17}H_{16}O_5$	100.00	300.10	300.90
6	3-O-methylquercetin	$C_{16}H_{12}O_7$	11.73	316.05	314.95
7	Myricetin	$C_{15}H_{10}O_8$	5.78	318.03	316.85
8	Coumaroylquinic acid	$C_{16}H_{18}O_8$	30.55	338.10	336.90
9	Esculin	$C_{15}H_{16}O_9$	11.26	340.07	338.85
10	Luteolin 7-O-glucuronide	$C_{21}H_{18}O_{12}$	5.65	462.08	463.00
11	Sarcosine, N-(2-trifluoromethylbenzoyl)-, heptadecyl ester	$C_{28}H_{44}F_3NO_3$	10.11	499.32	499.00
Stalk					
1	Thymol	$C_{10}H_{14}O$	73.80	150.10	148.90
2	t-butylammonium iodide	$C_4H_{12}IN$	7.86	201.05	201.05
3	2,3-dihydroxy-1-guaiacylpropanone	$C_{10}H_{12}O_5$	6.44	212.06	211.20
4	Chlorpropham	$C_{10}H_{12}ClNO_2$	14.11	213.00	213.05
5	2,4-dichlorobenzyl isothiocyanate	$C_8H_5Cl_2NS$	7.19	218.103	216.95
6	4-fluorobenzoic acid, 4-cyanophenyl ester	$C_{14}H_8FNO_2$	12.92	241.05	241.05
7	Benzoic acid, 2,4,6-trinitro-	$C_7H_3N_3O_8$	9.55	256.99	256.95
8	Norathyriol	$C_{13}H_8O_6$	7.74	260.03	258.85
9	Thiamine	$C_{12}H_{17}N_4OS$	100.00	265.11	265.85
10	Coumestrol	$C_{15}H_8O_5$	64.14	268.04	267.85
11	Genistein	$C_{15}H_{10}O_5$	11.52	270.05	269.75
12	Kaempferol	$C_{15}H_{10}O_6$	31.57	286.04	287.10
13	Catechin	$C_{15}H_{14}O_6$	7.62	290.07	287.95
14	Triadimefon	$C_{14}H_{16}ClN_3O_2$	11.89	293.74	293.10
15	Butanamide, N-(4-fluorophenyl)-2,2,3,3,4,4,4-heptafluoro-	$C_{10}H_5F_8NO$	6.79	307.02	307.05
16	Caftaric acid	$C_{13}H_{12}O_9$	12.35	312.04	311.15
17	4′O-methylepigallocatechin	$C_{16}H_{16}O_7$	25.45	320.09	320.95
18	Acetamide, N-(2-iodo-4-methylphenyl)-2,2,2-trifluoro-	$C_9H_7F_3INO$	8.87	328.95	328.95
19	Coumaroylquinic acid	$C_{16}H_{18}O_8$	18.28	338.10	336.90
20	Esculin	$C_{15}H_{16}O_9$	17.44	340.07	339.15
21	Bis(4-nitrophenyl) phosphoric acid	$C_{12}H_9N_2O_8P$	5.48	340.01	340.15
22	Sarcosine, n-pentafluorobenzoyl-, heptyl ester	$C_{17}H_{20}F_5NO_3$	6.50	381.13	380.95
23	Kaempferol 3-O-glucoside	$C_{21}H_{20}O_{11}$	8.36	448.10	447.20
24	Quercetin 3-O-galactoside	$C_{21}H_{20}O_{12}$	5.42	464.09	465.40
25	D-alanine, N-(3-fluoro-4-trifluoromethylbenzoyl)-, pentadecyl ester	$C_{26}H_{39}F_4NO_3$	7.19	489.28	489.30
26	Quercetin 3-O-(6″-malonyl-glucoside)	$C_{24}H_{22}O_{15}$	6.45	550.09	550.85
27	Apigenin 6,8-di-C-glucoside	$C_{27}H_{30}O_{15}$	15.95	594.15	593.00
28	Delphinidin 3-O-glucosyl-glucoside	$C_{27}H_{31}O_{17}$	5.72	626.90	625.00
28	Malvin	$C_{29}H_{35}ClO_{17}$	14.95	655.18	655.00
30	Riboflavin, 2′,3′,4′,5′-tetrabutanoate	$C_{33}H_{44}N_4O_{10}$	5.28	656.30	656.15
Flower					
1	Sarcosine, N-(3-bromobenzoyl)-, butyl ester	$C_{14}H_{18}BrNO_3$	11.2	328.20	327.25
2	Isradipine	$C_{19}H_{21}N_3O_5$	100.00	371.14	371.35
3	Bamifylline	$C_{20}H_{27}N_5O_3$	32.19	385.21	385.40
4	Sarcosine, n-pentafluorobenzoyl-, nonyl ester	$C_{19}H_{24}F_5NO_3$	24.25	409.16	409.25
5	Apigenin-7-O-glucoside	$C_{21}H_{20}O_{10}$	14.13	432.10	433.25
6	Naringenin 7-O-glucoside	$C_{21}H_{22}O_{10}$	11.48	434.12	435.35
7	CI-1029	$C_{28}H_{37}NO_4S$	22.68	483.24	483.25
8	L-glutamic acid, N-trifluoroacetyl-, bis(2,2,3,3,3-pentafluoropropyl) ester	$C_{13}H_{10}F_{13}NO_5$	10.66	507.03	507.35
9	Fumaric acid, 2,2,3,3,4,4,5,5-octafluoropentyl pentadecyl ester	$C_{24}H_{36}F_8O_4$	12.60	540.24	540.30
10	l-methionine, n-heptafluorobutyryl-, pentadecyl ester	$C_{24}H_{40}F_7NO_3S$	26.27	555.26	555.30
11	3-acetamido-2,4,6-triiodobenzoic acid	$C_9H_6I_3NO_3$	5.53	556.74	566.30
12	l-phenylalanine, n-heptafluorobutyryl-, pentadecyl ester	$C_{28}H_{40}F_7NO_3$	39.03	571.29	571.30

Table 4: (continued)

S. no	Compounds	Formula	RI	Theoretical (*m*/*z*)	Observed (*m*/*z*)
13	Apigenin 6,8-di-C-glucoside	$C_{27}H_{30}O_{15}$	29.11	594.15	595.30
14	Eriocitrin	$C_{27}H_{32}O_{15}$	5.98	596.17	597.25
Petiole					
1	Toloxatone	$C_{11}H_{13}NO_3$	9.12	207.09	206.85
2	Sinapic acid	$C_{11}H_{12}O_5$	100.00	224.06	224.9
3	Pentafluoropropanoic acid, 4-cyanophenyl ester	$C_{10}H_4F_5NO_2$	9.81	265.01	265.10
4	4-hydroxypropranolol	$C_{16}H_{21}NO_3$	26.87	275.15	275.10
5	Triadimefon	$C_{14}H_{16}ClN_3O_2$	13.17	293.09	293.20
6	Quercetin	$C_{15}H_{10}O_7$	5.17	302.04	302.95
7	Caftaric acid	$C_{13}H_{12}O_9$	13.25	312.04	311.25
8	p-coumaric acid glucoside	$C_{15}H_{18}O_8$	31.15	326.10	325.15
9	Esculin	$C_{15}H_{16}O_9$	17.28	340.07	339.20
10	D-alanine, N-(2,5-ditrifluoromethylbenzoyl)-, nonyl ester	$C_{21}H_{27}F_6NO_3$	5.65	455.19	455.25
11	Salvianolic acid B	$C_{36}H_{30}O_{16}$	21.18	718.15	719.65
12	Digitoxin	$C_{41}H_{64}O_{13}$	12.71	764.43	764.65

RI, retention index.

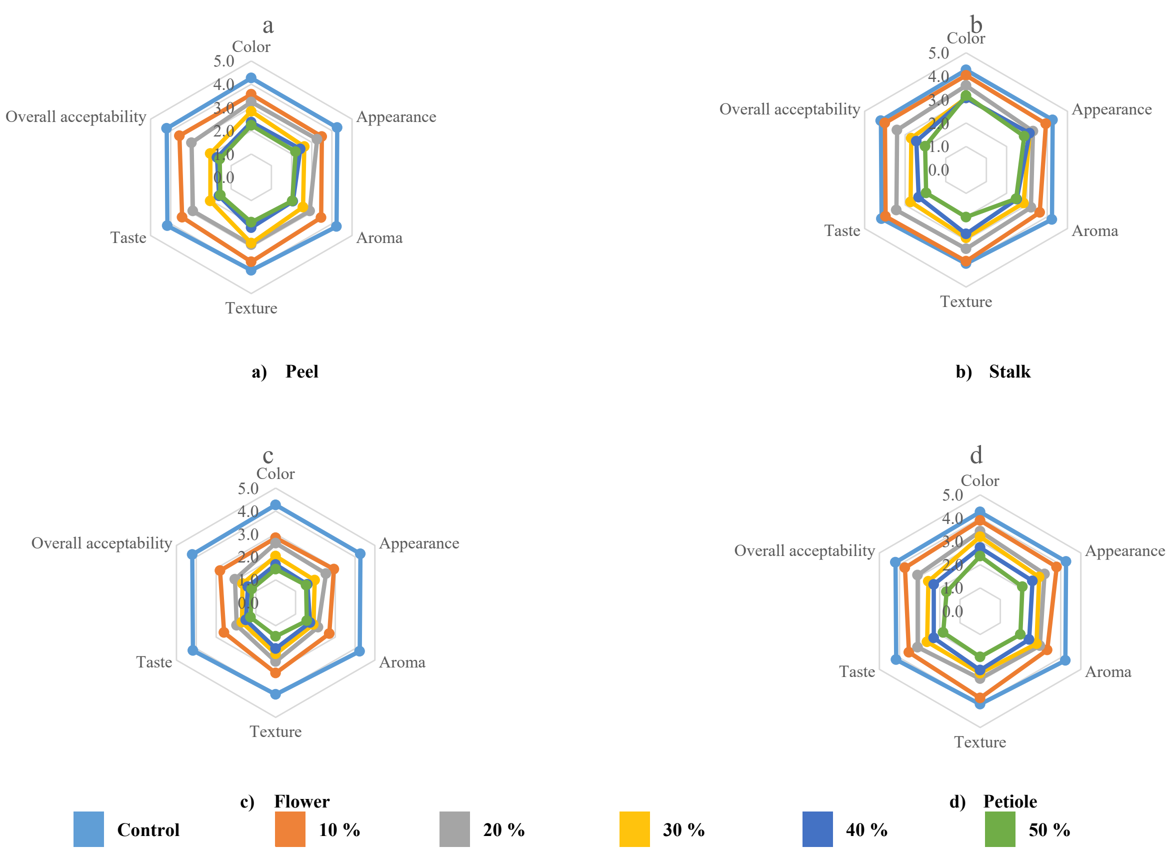

Figure 3: Sensory analysis of functional cookies developed with flour mix by SWP substitution.

biological activities such as antioxidant, anti-inflammatory, anti-fungal, anti-viral and anti-carcinogenic. Moreover, some of the compounds serve as neuro-stimulant, vaso-protective, neuroprotective acidifiers, and acidulants [37–39]. The detailed description of the phytochemicals is tabulated in Table 4 and the biological activities of the identified phytochemicals are reported in Table S7 of Supplementary Material.

3.5 Fuzzy logic analysis

The fuzzy analysis of developed cookies reveals that cookies developed with substitution of the stalk were most acceptable among panels, followed by petiole peel and flower [22, 23]. The results for the sensory analysis are reported in Figure 3, and similarity values are given in Supplementary Material Table S8. Waste streams such as stalk and petiole have the lowest shallot flavor, which helps them to get better sensorial acceptability. Shallot flower found to be pungent may be due to containing a high amount of sulfur compounds which when comes in contact with air forms compounds such as allithiolanes imparting bitter taste [40]. This may be the reason for the bitter taste in cookies substituted with shallot flower. Moreover, flavonoids are also reported to impart a bitter taste [41].

4 Conclusions

Proximate analysis of shallot waste streams revealed an abundance of fiber and ash content and protein, particularly in shallot flower. Substitution of these waste streams in RWF improved functional properties such as WAC, OAC indicating its suitability for the development of bakery products. However, the decrease in pasting properties will limit the application to lower substitutions only. The cookies developed with shallot waste substitution showed improved nutritional quality with the increased fiber, ash, total phenol, and total flavonoid content. Nevertheless, the higher substitutions showed undesirable changes in color and textural quality parameters of developed cookies. Similar results were reflected in the sensory analysis. The waste substitution up to 10% was acceptable for stalk and petiole while up to 5% for peel in terms of total cookies weight. This represents the need for efforts to improve the acceptability of developed products with higher substitutions. Apart from value addition, studies need to be undertaken to exploit shallot waste to introduce into various food systems for functional, nutritional, and sensory improvement.

Acknowledgment: The authors acknowledge the Ministry of Food Processing Industries (MOFPI), Government of India for funding the research work, and the Indian Institute of Food Processing Technology, Thanjavur, for providing the facilities to conduct the study successfully.
Author contributions: Bhosale Yuvraj: Conceptualization, methodology, experimentation, data curation and writing original draft. Thivya P: Data curation and writing original draft. Shery MV: Methodology and data curation. Hema V: Conceptualization and methodology. Sinija VR: Conceptualization, methodology, reviewing, funding aquisition and supervision.
Research funding: The authors acknowledge the funding received from the Ministry of Food Processing Industries, Government of India (Grant no: – Q11/14/2018-R&D).
Conflict of interest statement: The authors declare no conflict of interest.

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Supplementary Material: The online version of this article offers supplementary material (https://doi.org/10.1515/ijfe-2021-0169).