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Physico-Chemical, Organolyptical and Microbiological Characteristics of Substituted Cupcake by Potato Processing Residues

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Abstract

Utilization of potato processing residues to produce a low caloric cupcake in present study was targeted. The functional properties of wheat flour (WF 72%) and dried potato peel varieties [Hermus (PPH) and Russet (PPR)] were carried out. Consequently, WF was partially substituted by both potato peels (PP) at 5% - 20% to prepare mixtures for cupcake making. Approximate chemical composition and physical characteristics were determined. Rheological parameters of prepared formulas were assayed using Mixolab. Moreover, total phenolic compounds (TPC) and relative antioxidant activity (AOA) were evaluated. Quality parameters such as thiobarbituric acid (TBA), staling and microbiological attributes during storage were determined. In addition, a sensory evaluation of different substituted cupcake was performed as well. Results indicated that PPR had the highest water absorption capacity (WAC), oil absorption capacity (OAC) and swelling capacity (SC) followed by PPH then WF flours. Indeed, substituted WF with both PP at 5% and 10% didn't influence the thermo-mechanical properties including dough time development, stability, viscosity, gluten and starch characteristics drastically. Likewise, this substitution levels didn't affect the organoleptic properties which were confirmed by panelists, cupcake external and cross sections. Substituted WF by 5% - 10% PP recorded sensory scores aftermost WF. Mildly, WF cupcake was higher in protein and fat contents than WF-PP cupcakes while lower in crude fiber. The WF-PP cupcakes at different substituted levels recorded lower energy value than WF cupcakes. Arguably, increasing both PP levels increased the TPC and AOA especially for WF-PPR cupcakes. Afterwards, WF-PPR 15% and 20% recorded the highest TPC and AOA contents to be 2.32 mg GAE g^{-1} dw and 3.44 μmol TE g^{-1} dw, respectively. No significant difference (p > 0.05) was found between WF-PP at 5% and WF cupcakes in physical and staling properties. WF-PPR cupcakes at different concentrations were lower TBA than WF cupcakes and mostly stable during storage period. It was revealed that substitution levels of 5% and 10% with PPH and PPR produced acceptable cupcakes which did not significantly differ from WF cupcakes.

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Keywords

Low Caloric Cupcake, Potato Peel Residues, Rheological Properties, Quality, Stability, Revalorization

1. Introduction

Cakes are the most consumed bakery product owing to unique products and are always used in festivals as well as in joyous celebrations [1]-[3]. It's increasing worldwide by about 1.5% per year [4]. It's usually made from soft WF at higher extraction caused deficient in fibers and phytochemicals. Recently, alternative fibers from different sources are available which may provide fibers and phytochemicals as natural components, like fruit, vegetable and their residues [5]. Potato (*Solanum tuberosum* L.) is one of the main foods in human diets which grow in more than 100 countries. It's the fourth largest crop grown worldwide [6], with world annual production of 367.75 million tons (FAO) [7]. However, peels are the main residues of potato processing which present up to 3% - 5% causing many environmental problems [8]. PP is a good source of natural antioxidants [9] [10], phenolic compounds [8] [11] [12] especially purple potato variety "Russet" [13]-[16] and fibers [17].

Many epidemiological studies assert that fibers consumption helps to reduce obesity, some cancer kinds and cardiovascular diseases [18]-[21]. Therefore, the fibers consumption recommended to be up to 20 - 35 g daily [22]. Newly, some researches were mentioned that food residues could be incorporated into cake making such as carrot leafs [23], watermelon rinds and sharlyn melon peels powders [24], potato peels [17] [25], flaxseeds [26] and apple pomace [27] [28]. Indeed, incorporating the PP could increase its added-value, decrease the cupcake total manufacturing coast and provide phytochemicals, antioxidants into the human diets.

Therefore, the aim of this study was to study the applicability of WF 72% substitution by both dried PP powder in cake making to produce low caloric cupcake. To achieve this aim, functional properties of WF and PP were determined. Consequently, approximate chemical composition, physical characteristics, rheological parameters of prepared mixtures were investigated. Moreover, TPC and AOA were evaluated. Quality parameters and sensory evaluation of different substituted cupcake were performed as well.

2. Material and Methods

2.1. Chemicals and Media

1,1-diphenyl-2 picrylhydrazyl radical (DPPH$^{\bullet}$) and 6-hydroxy-2,5,7,8-tetramethylchroman carboxylic acid (Trolox) were obtained from Sigma Aldrich, Germany. Folin-Ciocalteu reagent, Fluka Co., France, Gallic acid, Serva, fine Biochemical, New York. Tryptic glucose yeast agar (TGYA, code No. 4021452), Rose Bengal agar (RBA, Biolife code No. 401992) and Violet red bile agar (VRBA, code No. 402185), were obtained from Biolife, Italy.

2.2. Raw and Baking Materials

1) Both PP (PPH and PPR) from the crop of session 2012 were obtained from Egypt Foods Co., Industrial Zoon, Quesna City, Egypt.

2) Soft WF (72% extraction) were obtained from Cairo South Co. of Milling, Cairo, Egypt.

3) Baking ingredients such as sugar (sucrose; a commercial grade), salt, skimmed milk powder, shortening, fresh whole egg, baking powder and vanilla were obtained from local supermarket, Tukh City, Qaliuobia, Egypt.

2.3. Potato Processing Residues Preparation

The obtained PP residues in fresh status were transferred immediately to the analytical lab. Both PP were dried by oven dryer (Tit Axon S.R.L via Canova, Italy) at 40˚C - 50˚C gradually for 12 h. Subsequently, the dried peels were milled by grinder (Severin, Type 3871, Germany) and passed through a 60 mesh sieve to obtain fine homogenous powder. The PP meals were immediately packed in dark glass jars then kept at −18˚C ± 1˚C until use.

2.4. Processing of Cupcakes Formulas

All formulas of substituted WF at different substitution levels by both PP were summarized in **Table 1**. The processing method of cupcake was taken typically according to A.A.C.C. [29] in steps sequence as: The shortening was melted thoroughly; sugar and salt were added then mixed vigorously. The whole egg was mixed with vanillia and whipped until got puff and smooth like-cream texture. Additionally, substituted WF with both PP (PPH and PPR) at 5%, 10%, 15% and 20% were mixed individually with 2.15% baking powder and 4.30% skimmed milk powder then added gradually to whipped egg mixture. This mixture was mixed gently until got homogenous dough using Hand mixer (MK-H4-W, Panasonic Co, Malaysia). After getting appropriate texture the dough was poured into paper cups and backed at 180˚C ± 5˚C for 30 - 35 min. The baked cupcakes were cooled down at room temperature, then packed into aluminum foil bags then stored at room temperature for 8 days. Samples were taken during the storage periods at 0, 5, 8 day intervals for analysis. Finally, the photos for external and cross-sections were taken directly after the end of baking using an Olympus digital camera 8 MP model FS-32.

2.5. Analytical Methods

2.5.1. Determination of Functional Properties of Wheat Flour and Both Potato Residues

Both PP and WF were subjected to functional properties analysis. WAC and OAC were determined according to the modified method by Heywood *et al.* [30]. Fifty gram sample from each prepared PP or WF were dispersed in 285 ml distilled water or oil in a 500 ml centrifuge bottle. Bottles were agitated for 10 min then centrifuged at 4000 × g for 30 min. After decanting the supernatant, each bottle was weighed and WAC or OAC was calculated as (g of water or oil g^{-1} flour dw). Also, SC was measured using the bed volume technique as described by Kuniak and Marchessault [31]. Sample about 0.5 - 1.0 g was weighed into a 15 ml falcon tube, 10 ml of phosphate buffer were added and the suspension had been stirred. After equilibration for 16 h, the volume was recorded and expressed as $ml·g^{-1}$ dw.

2.5.2. Approximate Chemical Composition

WF cupcakes and different substituted PP cupcakes were subjected immediately to chemical composition analysis [moisture, ash, crude fat, crude fiber and crude protein], according to A.A.C.C. [32]. The available carbohydrates content was calculated by difference according to FAO [33]. To calculate the food energy value, the main components were converted using conversion factors as [16.75 $kJ·g^{-1}$ for (proteins and available carbohydrates), 37.68 $kJ·g^{-1}$ for (fats) and 8.37 $kJ·g^{-1}$ for (fiber)] according to FAO [33].

2.5.3. Physical Characteristics

The normal weight (g) of baked cupcakes was determined individually within one hour after baking and the

Table 1. Raw ingredients of processed cupcake.

Ingredients	Weight (g)
Soft wheat flour (72% extraction)	250.0
Sugar	125.0
Salt	3.50
Skimmed milk powder	25.0
Shortening	53.50
Fresh whole egg	110.0
Baking powder	12.50
Vanillia	2.0

average was calculated. The volume (cm^3) of different substituted cupcakes was determined by rape seeds displacement method according to A.A.C.C. [32]. Also, the specific weight was calculated for different substituted cupcake.

2.5.4. Total Phenolic Compounds and Antioxidant Activity

1) Total phenolic compounds

The TPC of methanolic extracts from different cupcake formulas was determined calorimetrically using the Folin-Ciocalteau method according to Sudha *et al.* [28]. One g of defatted sample [after refluxing with chloroform and petroleum ether, (1:1 v/v) followed by drying] was mixed with 10 ml methanol, then stirred and centrifuged at 2000 × g for 15 min to obtain clear methanolic extract. Appropriate extracts dilutions were reacted with Folin-Ciocalteau reagent then 2 ml of 10% Na_2CO_3 were added. After 1 h at ambient temperature, the absorbance was measured at 765 nm and The TPC was expressed as milligram gallic acid equivalents per gram sample (mg GAE g^{-1} dw) using this equation:

$$Y = 0.0201x + 0.0538 \qquad (R^2 = 0.99) \tag{1}$$

where: Y is the concentration and x is the absorbance.

2) Determination of antioxidant activity

The antioxidant activity (AOA) of different substituted cupcake was determined using DPPH$^{\bullet}$ assay according to Lee *et al.* [34] with minor modification. A 0.1 ml for methanolic extract for each sample was vortexed for 30 s with 3.9 ml of DPPH$^{\bullet}$ solution and left to react for 30 min, afterword the absorbance at 515 nm was recorded and expressed as micromoles of trolox equivalents (TE) per gram of dry weight (μmol TE g^{-1} dw).

2.6. Determination of Some Quality Parameters for Different Substituted Cupcakes during Storage

Determination of TBA and Staling

The amount of lipid oxidation in different substituted cupcakes was determined by the 2-thiobarbituric acid (TBA) method according to A.O.C.S. [35]. However the staling of different baked cupcakes containing different levels of PP meal was measured by alkaline water retention capacity (AWRC) according to A.A.C.C. [32].

2.7. Rheological Parameters

The effect of both PP meal substitution at 5%, 10%, 15% and 20% on WF thermo-mechanical and rheological parameters were determined using Mixolab apparatus (20 AV MARCELLIN BERTHELOT, CHOPIAN, France) according to Dubat [36].

2.8. Organoleptic Properties

The organoleptic properties of different substituted cupcakes was carried out in a standardized test room in morning sessions (11:00-13:00 h) by properly 28 well trained panelists according to A.A.C.C. [32]. They were selected if their individual scores in 10 different tests showed a reproducibility of 90%. Mineral water was used by the panelists to rinse the mouth between samples. Cupcake samples were left to cool at room temperature for 1 h after baking, then cut with a sharp knife and subjected to panel test. The score was distributed as: 40: crumb cells (10: uniformity, 10: cells size, 10: walls thickness and 10: color), 30: texture (10: moistness, 10: tenderness and 10: softness), 10: crust color, 10: odor, 10: taste, and 100: overall acceptability. Results were expressed as mean ± SD.

2.9. Microbiological Attributes

Total bacteria count (TBC), coliform group (CG) and yeast & molds (Y & M) were evaluated periodically in different substituted cupcakes during different storage periods. Under sterile conditions, serial dilutions were prepared and inoculated then TGYA, RBA and VRBA were poured. All plates were incubated at 37˚C for 48 h for TBC and CG while at 28˚C for 3 - 5 days for Y & M. All microbiological examinations were performed in triplicates.

2.10. Statistical Analysis

The statistical analysis was carried out using SPSS program (ver. 19) with multi-function utility regarding to the experimental design under significance level of 0.05 for the whole results and multiple comparisons were carried out applying LSD with Duncan according to Steel *et al.* [37].

3. Results and Discussion

3.1. Functional Properties of Wheat Flour and Potato Peels Residue

The functional properties including WAC, OAC and SC of WF 72% and both PP residue were determined, data were tabulated in **Table 2**. The obtained data observed that PPR and PPH had higher WAC, OAC and SC than WF flours significantly. However, no significant difference ($p > 0.05$) was found between PPH and PPR in WAC, while significant difference ($p < 0.05$) was observed between them in OAC and SC. These results are in agreements with some publications [38] [39]. Recently, Dhingra *et al.* [17] remarked that PP is considered as a good source of dietary fibers which may be efficiently usable in bakery products.

3.2. Effect of Wheat Flour Substitution by Potato Peels Residue on Rheological and Thermo-Mechanical Parameters Determined by Mixolab

The effect of WF substitution by PP residue on protein and starch properties was monitored using Mixolab apparatus. Mixolab is a new instrument that can monitor dough rheological properties during mixing under controlled conditions. It is allowable to perform continuous rheological measurements of dough into a simulation of thermal-processing. In Mixolab curve, there are five parameters should be considered; (C_1): maximum torque of the initial mixing stage, (C_2): protein weakening, (C_3): starch gelatinization, (C_4): physical breakdown of gelatinized starch granules, and (C_5): starch retrogradation as explained by Kahraman *et al.* [40].

The effect of WF substitution by PP residue on the absorption, mixing, gluten, viscosity, amylase and retrogradation were investigated, results were presented in **Figure 1(a)** and **Figure 1(b)**. Partially substituted WF by PPH and PPR at 5% - 20% altered the dough properties as recorded in their Mixolab profiles. The absorption was increased rapidly with increasing the PPH and PPR levels. Gluten, amylase and retrogradation were decreased in substituted WF with more than 10% PP. However, the viscosity wasn't changed drastically (**Figure 1(a)** and **Figure 1(b)**). The WF-PPH 20% recorded the highest absorption, while the WF was lower absorption than all substituted WF. Generally, both PP caused increasing in absorption, owing to their contents of starch and fibers. Mildly, the viscosity and amylase parameters weren't affected significantly. Thereby, the stable viscosity formulas had harder texture which may be useful to avoid mechanical damage of products during transport and handling [41]. Particularly, both PP reduced the gluten and retrogradation characteristics when compared with WF. These phenomena may owe its chemical composition exhibit low protein contents.

Stability and water absorption are one of the most important properties. The effects of PP residue incorporated into WF on those properties were tabulated in **Table 3**. Not only WF had the high stability but also the WF-PPR 10% had higher stability than all substituted formulas to be 11.17 and 10.97 min, respectively. Conversely, the WF-PPH and PPR 20% recorded lower stability than all formula to be 10.47% and 10.57%, respectively; this may be due to their higher fibers content. The higher fibers content caused decreasing in dough stability as mentioned before by Torbica *et al.* [42].

Table 2. Functional properties of wheat flour and potato peels residues.

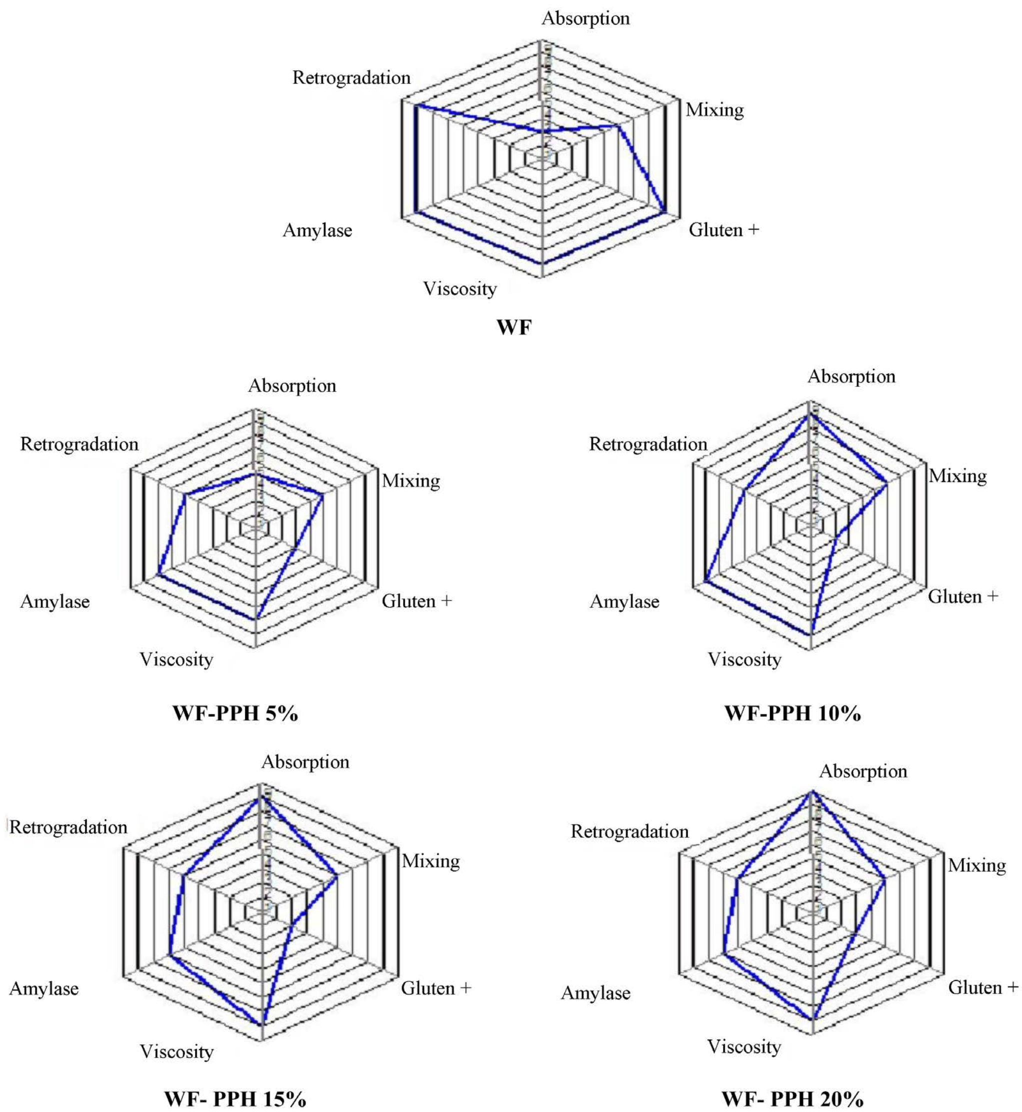
Item	Functional properties		
	WAC [g of water g^{-1} dw]	OAC [g of oil g^{-1} dw]	SC [ml·g^{-1} dw]
Potato peel "Hermus" (PPH)	5.79 ± 0.07^b	2.82 ± 0.13^b	7.00 ± 0.20^b
Potato peel "Russet" (PPR)	5.98 ± 0.15^b	3.25 ± 0.09^c	7.77 ± 0.25^c
Wheat flour* (WF)	3.37 ± 0.06^a	1.82 ± 0.09^a	4.60 ± 0.17^a

[a,b,c]: Means with the same letter in the same column are not significantly different ($p > 0.05$). *Wheat flour contained: 6.30, 10.33, 10.12, 110.76 and 850.09 g·kg^{-1} dw for ash, fat, fibers, protein and available carbohydrates, respectively as well as 110.50 g·kg^{-1} moisture.

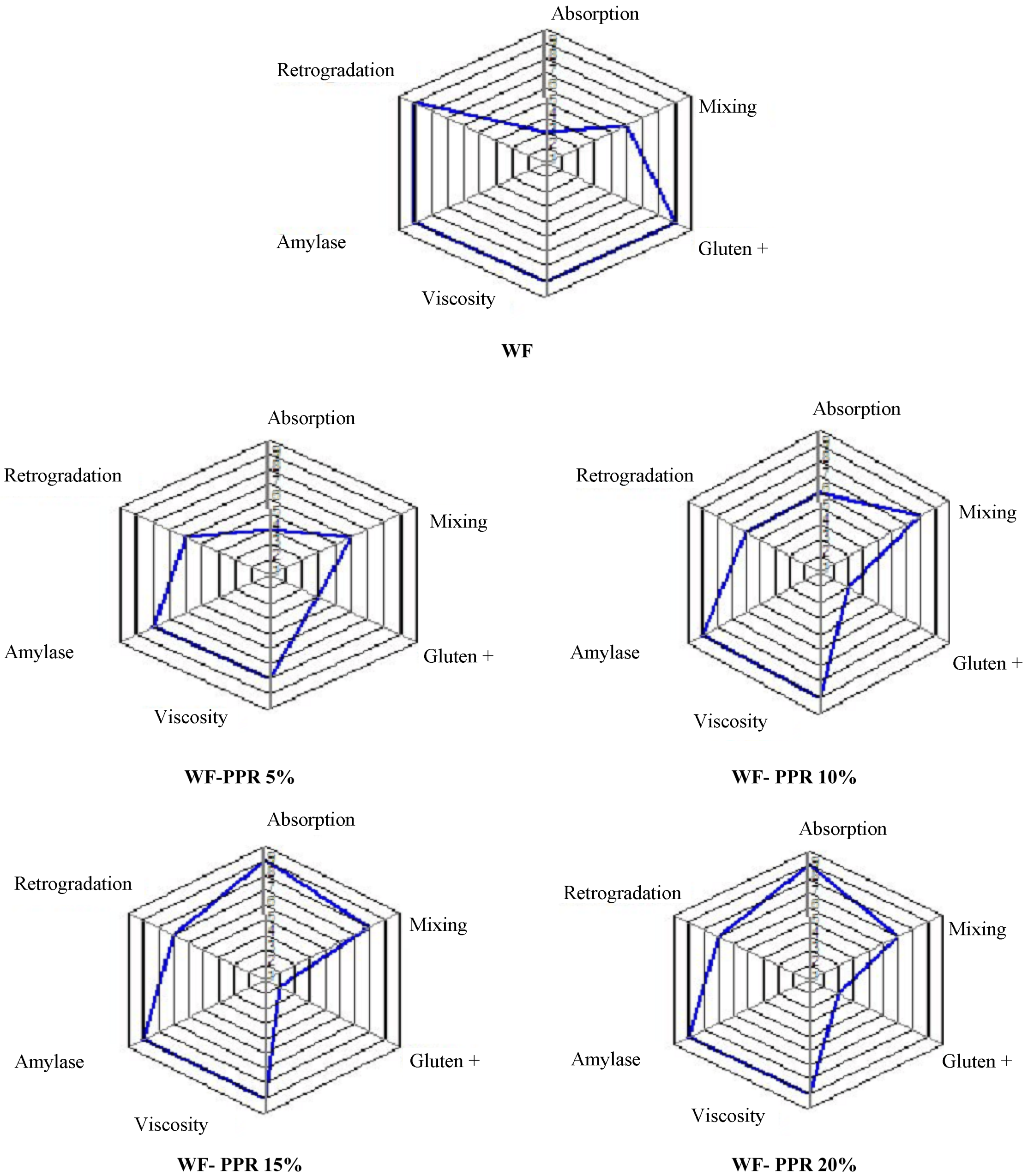
Table 3. Water absorption and stability of wheat flour and substituted WF by potato residues.

Flour blends*	Substitution level (%)	Mixolab parameters	
		Water absorption (% b14)**	Stability (min)
Wheat flour	0	55.00	11.17
WF-PPH	5	57.60	10.78
	10	61.30	10.55
	15	63.20	10.82
	20	67.80	10.47
WF-PPR	5	56.80	10.58
	10	58.60	10.97
	15	61.40	10.60
	20	61.30	10.57

*These blends were composed of wheat flour substituted by PP residues at different concentration. **These data was basically calculated on 14% moisture content in WF.



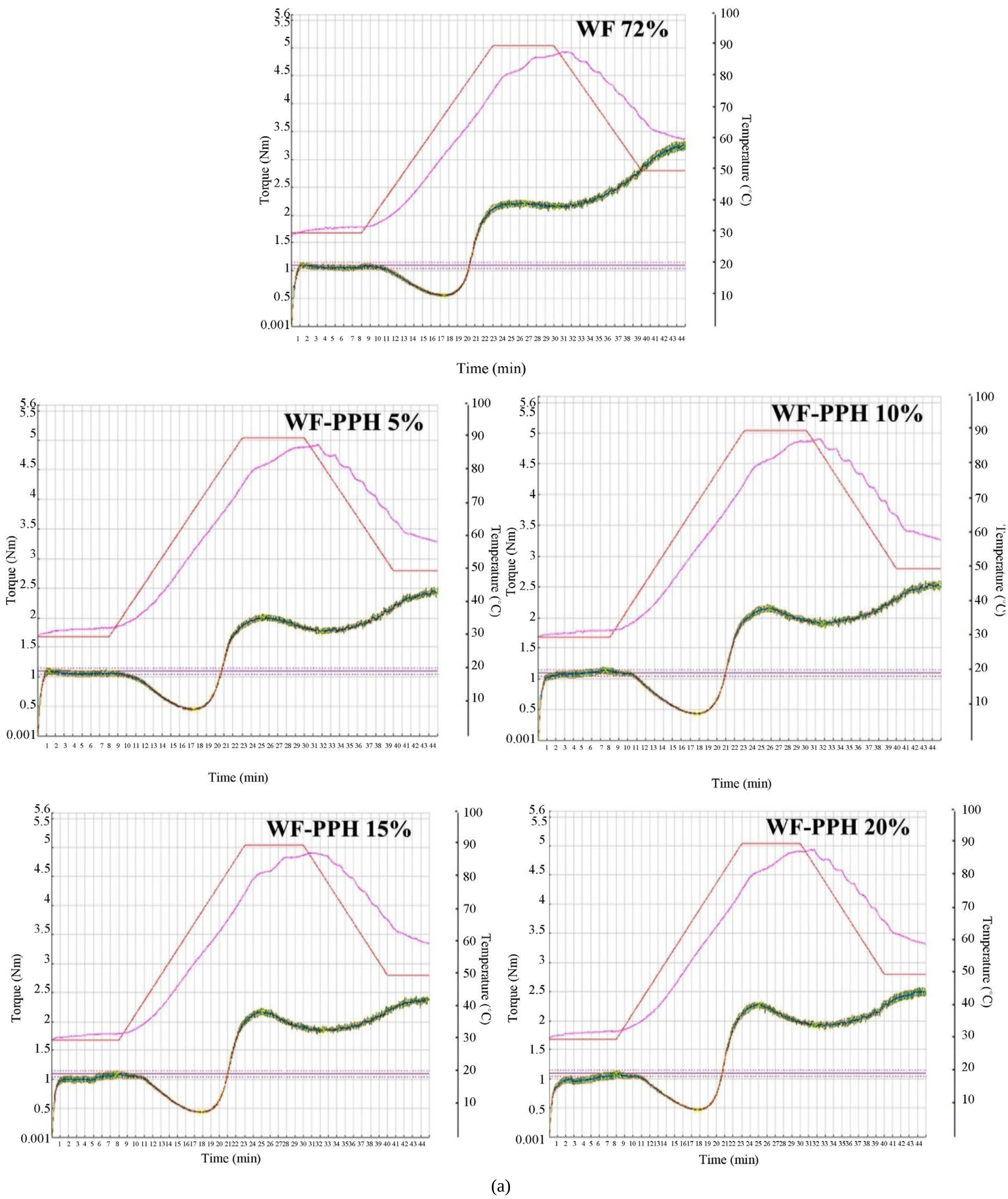
(a)



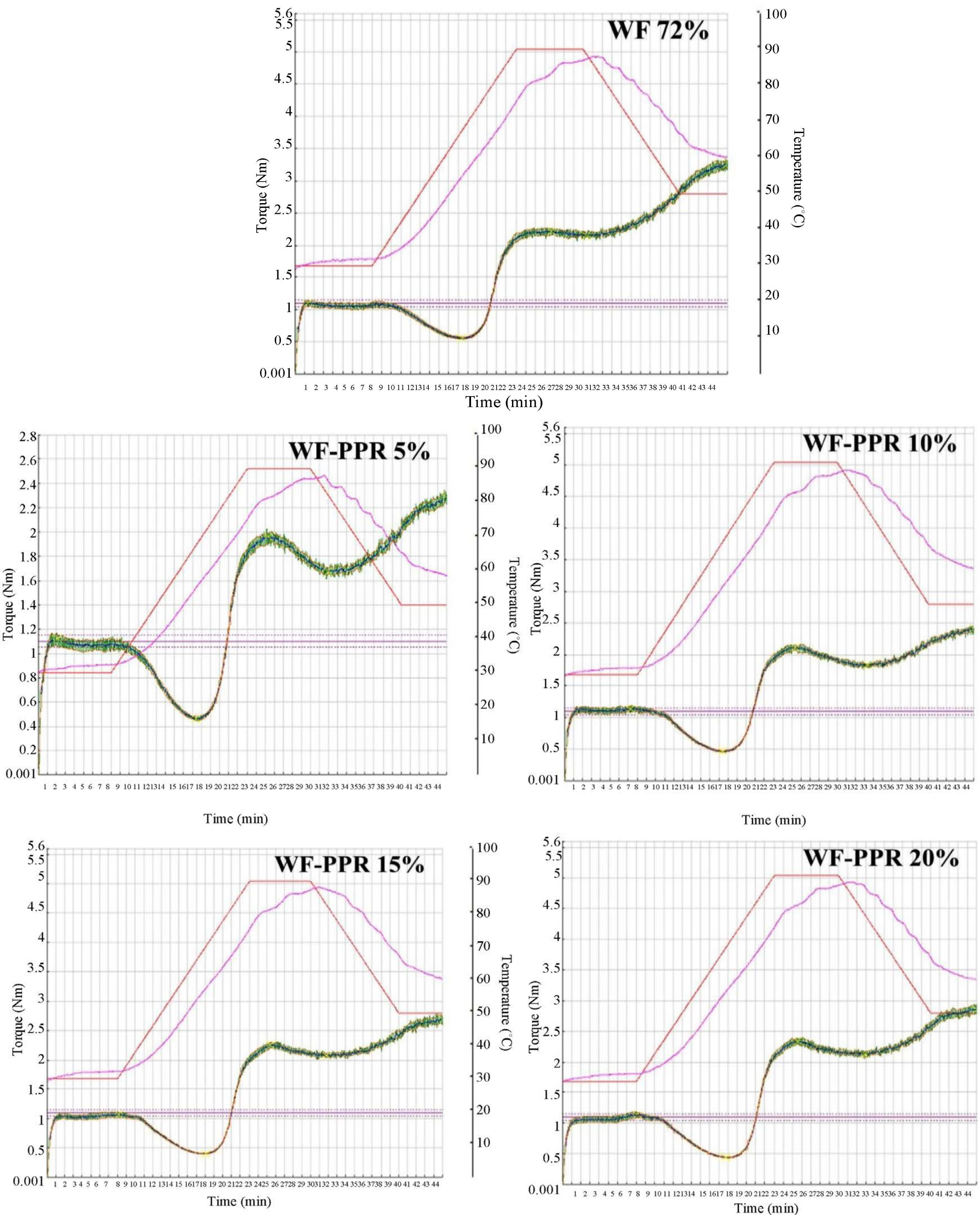
(b)

Figure 1. (a) A Mixolab typical target profile of wheat flour 72% (WF) and substituted WF by different substitution levels of PPH at 5%, 10%, 15%, and 20% (w:w); (b) A Mixolab typical target profile of wheat flour 72% (WF) and substituted WF by different substitution levels of PPR at 5%, 10%, 15%, and 20% (w:w).

Conversely, substitution of WF with PPH recorded higher water absorption than PPR. For instance, the WF-PPH 20% recorded the highest water absorption to be 67.80%. As shown in **Figure 2**, it seems to be that there are differences in the thermo-mechanical and rheological parameters of substituted WF at arranges of 30˚C depend on residue type and substitution level. Generally, adding 5% of both PP wasn't affected the dough time development. Also, the increasing of PP levels especially PPR resulted in longer dough development time due to their contents of starch to be 8.13 and min 8.15 for WF-PPR 15% and 20%, respectively. As for C_2, negligible difference was observed among all formulas. Thus, the WF-PPR 15% scored the lowest torque in this period to be 0.40 Nm. In contrary, WF recorded the highest torque compared with other formulas to be 0.56 Nm. This may reflects the strength and weakening of protein for each formula including WF [42] [43]. For C_3, the WF-PPR 5% was the lowest torque in C_4 and C_5 periods, but the WF was the highest torque in C_4 and C_5, respectively. This may be due to the properties of starch during heating and cooling. Also, in these periods the variation in time among formulas was negligible. Until now and to the best of our knowledge, no work about the thermo-mechanical and rheological parameters of WF incorporated PP were found. Finally, the results are in agreements with Kahraman *et al.* [40] who reported that, making a good cake flour should have low in C_3, C_4 and C_5 values which indicate the importance of the starch phase of used flour in making of cake.



(a)



(b)

Figure 2. (a) Thermo-mechanical and rheological parameters of substituted wheat flour (72%) with different substitution levels of PPH at 5%, 10%, 15%, and 20% (w:w); (b) Thermo-mechanical and rheological parameters of substituted wheat flour (72%) with different substitution levels of PPR at 5%, 10%, 15%, and 20% (w:w).

3.3. Organoleptic Properties of Different Substituted Cupcakes with Potato Peels Residue

The effect of substituted WF by PP residue used in making of cupcake on organoleptic properties were studied, data was presented in **Table 4**. Twenty eight trained panelists were asked to judge cupcake parameters include texture properties (moistness, tenderness and softness), crumb cells (uniformity, size, thickness and color),

Table 4. Organoleptic properties of WF and different substituted WF cupcakes with potato peels residues.

Cupcake formula	Substitution level (%)	Organoleptic attributes										
		Crust color (10)	Crumb cells				Texture			Odor (10)	Taste (10)	Overall acceptability (100)
			Thickness (10)	Size (10)	Uniformity (10)	Color (10)	Softness (10)	Tenderness (10)	Moistness (10)			
WF	0	9.30 ± 0.60^{e}	8.48 ± 1.05^{e}	8.88 ± 1.17^{f}	8.46 ± 1.40^{f}	9.30 ± 0.66^{f}	9.05 ± 0.97^{e}	8.82 ± 1.02^{g}	8.66 ± 0.96^{e}	8.93 ± 0.86^{e}	9.11 ± 0.74^{e}	95.11 ± 6.37^{g}
WF-PPH	5	7.64 ± 0.95^{cd}	7.36 ± 1.50^{cd}	7.54 ± 1.50^{cde}	6.89 ± 1.83^{d}	7.29 ± 1.61^{e}	7.71 ± 1.46^{de}	7.59 ± 1.57^{f}	7.75 ± 1.46^{d}	6.79 ± 1.93^{abcd}	6.82 ± 1.98^{cd}	79.64 ± 14.06^{f}
	10	6.91 ± 1.47^{bc}	7.07 ± 1.54^{cd}	6.86 ± 1.88^{abc}	6.71 ± 1.86^{abcd}	6.27 ± 1.57^{bcd}	7.14 ± 1.51^{cd}	6.79 ± 1.55^{bcde}	6.89 ± 1.64^{bcd}	6.96 ± 1.97^{bcd}	6.86 ± 1.72^{cd}	77.36 ± 15.17^{ef}
	15	6.43 ± 2.04^{ab}	6.50 ± 1.97^{abc}	6.75 ± 2.10^{abc}	7.07 ± 1.54^{bcde}	6.14 ± 1.82^{abcd}	6.79 ± 1.85^{abcd}	6.14 ± 2.16^{abc}	6.89 ± 1.79^{bcd}	6.43 ± 2.17^{abc}	6.89 ± 2.02^{cd}	74.00 ± 17.56^{def}
	20	6.04 ± 1.82^{a}	6.00 ± 1.74^{a}	6.04 ± 1.64^{ab}	6.18 ± 0.94^{ab}	5.68 ± 1.36^{ab}	6.43 ± 1.67^{abc}	5.64 ± 1.89^{a}	6.14 ± 1.33^{ab}	5.89 ± 1.73^{a}	6.14 ± 1.82^{abc}	63.86 ± 15.61^{bc}
WF-PPR	5	7.82 ± 1.33^{d}	6.86 ± 2.21^{abc}	6.57 ± 2.66^{abc}	6.50 ± 2.30^{abc}	7.32 ± 1.54^{e}	7.00 ± 1.66^{bcd}	6.18 ± 1.83^{abc}	7.11 ± 1.47^{bcd}	7.36 ± 1.64^{cd}	6.89 ± 1.50^{cd}	74.96 ± 14.04^{def}
	10	7.00 ± 1.33^{bcd}	7.00 ± 1.52^{bcd}	6.96 ± 1.50^{bcd}	6.46 ± 1.67^{abc}	6.84 ± 1.52^{cde}	6.82 ± 1.94^{abcd}	6.36 ± 1.59^{abcd}	6.50 ± 1.62^{abc}	7.18 ± 1.52^{cd}	6.39 ± 1.57^{bcd}	72.11 ± 15.22^{cdef}
	15	6.29 ± 1.54^{ab}	6.54 ± 1.43^{abc}	6.36 ± 1.54^{ab}	6.18 ± 1.68^{ab}	5.71 ± 1.96^{ab}	6.57 ± 2.17^{abc}	6.46 ± 2.17^{abcd}	6.29 ± 2.12^{ab}	6.50 ± 1.64^{abd}	5.54 ± 1.75^{ab}	63.96 ± 17.55^{bc}
	20	6.04 ± 1.23^{a}	6.14 ± 1.15^{ab}	5.89 ± 1.26^{a}	5.82 ± 1.33^{a}	5.32 ± 1.68^{a}	5.82 ± 1.91^{a}	5.68 ± 1.79^{a}	5.57 ± 1.73^{a}	6.00 ± 1.41^{ab}	5.32 ± 1.68^{a}	54.57 ± 16.52^{a}

[a,b,c]: Means with the same letter in the same column are not significantly different ($p > 0.05$).

(crumb color, odor and taste) and overall acceptability as well. Surely, significant differences ($p < 0.05$) were observed between cupcake formulas and WF cupcakes in all organoleptic characteristics. Increasing of PP affected dramatically the organoleptic properties. For example, the higher and the lower overall acceptability was observed for WF and WF-PPR 20% cupcakes to be 95.11% and 54.47%, respectively. Also, the lowest concentration of PP cupcakes was aftermost WF cupcakes. Generally, WF-PPR 5% cupcake was followed the WF cupcake in crust color scores, whereas the WF-PPH and WF-PPR 20% cupcakes recorded lower crust color than all formulas. Regarding the crumb cells properties, the WF-PPR 20% cupcake recorded the lowest formula in color, uniformity and size, while the WF-PPH 20% cupcake was the lowest formula in thickness property. Not only WF-PPH 5% cupcake was similar to WF cupcake but also significant differences ($p < 0.05$) in texture properties were noticed between WF cupcake and different cupcakes formulas. Likewise, WF-PPR 20% cupcake was the lowest formula in softness, moistness and taste. In contrast, the WF-PPH 20% cupcake was the lowest formula in tenderness and odor characteristics. Surly, data in **Figure 3** illustrated that the addition of PP residues at 5% or 10% wasn't influenced the organoleptic properties as remarked in external and cross sections of cupcake when compared with WF cupcake. The increasing of PP residue leads to increase the dark color and coarser textures. However, these results are agreed and supported by previous results of Al-Sayed and Ahmed [24].

3.4. Approximate Chemical Composition of Different Substituted Cupcakes with Potato Peels Residue

The proximate chemical composition of baked cupcakes from WF and substituted WF by PP residue at different concentration was determined; data was tabulated in **Table 5**. Mildly, adding of PP residue increased the moisture and ash contents. WF-PPR 20% cupcake recorded the highest moisture and ash contents to be 30.88 and 2.43%, respectively. WF cupcake was higher in protein content than other cupcakes to be 8.97%. Whereas, no significant difference ($p > 0.05$) had been found between all substituted and WF cupcake. Addition of both PP residues especially with high concentration purposed to increase the crude fibers. Indeed, the WF cupcake was lower in crude fibers than both PP cupcakes. No significant difference ($p > 0.05$) was found between both PP cupcakes at 5% and 10% substitution level and WF cupcake. The incorporated PP into cupcake at different concentrations recorded lower energy value than WF cupcake. To emphasize that, the WF-PPR 20% cupcake was the lowest energy value to be 1257.90 $kJ\cdot g^{-1}$. These results are in agreement with some previous studies [4] [24] [44] [45].

Table 5. A proximate chemical composition of WF and different substituted WF cupcakes with potato peels residues.

Cupcake formula**	Substitution level (%)	Compounds						
		Moisture*	Ash■*	Crud protein■*	Crud fat■*	Crud fiber■*	Available carbohydrate■*	Energy value ($kJ\cdot g^{-1}$)■
WF	0	26.26 ± 1.10^{a}	1.45 ± 0.24^{a}	8.97 ± 0.17^{d}	9.79 ± 1.84^{abc}	0.70 ± 0.25^{a}	79.80 ± 2.06^{a}	1364.90 ± 5.29^{de}
WF-PPH	5	26.90 ± 0.44^{ab}	1.72 ± 0.15^{abc}	6.90 ± 0.93^{abcd}	8.45 ± 0.67^{ab}	0.86 ± 0.25^{ab}	82.93 ± 1.41d^{b}	1334.66 ± 7.06^{cde}
	10	29.28 ± 1.97^{cdef}	1.83 ± 0.07^{bc}	5.73 ± 1.30^{a}	8.74 ± 2.10^{ab}	1.29 ± 0.41^{abc}	83.70 ± 2.38^{b}	1299.39 ± 9.31^{abc}
	15	29.30 ± 0.54^{cdef}	1.94 ± 0.02^{cd}	6.90 ± 1.46^{abcd}	7.38 ± 0.53^{a}	1.81 ± 0.55^{cde}	83.78 ± 1.82^{b}	1281.15 ± 2.35^{ab}
	20	28.98 ± 1.61^{bcdef}	2.32 ± 0.02^{e}	5.43 ± 1.26^{a}	8.66 ± 1.31^{ab}	1.96 ± 0.51^{cde}	83.59 ± 0.42^{b}	1302.55 ± 48.27^{bc}
WF-PPR	5	27.09 ± 0.59^{abc}	1.83 ± 0.16b^{c}	5.85 ± 1.59^{a}	8.52 ± 1.53^{ab}	0.77 ± 0.35^{ab}	83.80 ± 1.52^{b}	1333.72 ± 34.30^{cde}
	10	27.30 ± 1.07^{abcd}	1.94 ± 0.15^{cd}	6.46 ± 1.02^{abc}	8.90 ± 0.68^{ab}	1.39 ± 0.57^{abc}	82.70 ± 0.48d^{b}	1337.88 ± 20.83^{cde}
	15	28.17 ± 0.87^{abcde}	1.97 ± 0.14^{cd}	7.27 ± 2.42^{abcd}	7.47 ± 0.53^{a}	2.00 ± 0.52^{cde}	83.29 ± 3.02^{b}	1303.84 ± 23.88^{bc}
	20	30.88 ± 0.73^{f}	2.43 ± 0.52^{e}	5.65 ± 0.59^{a}	7.73 ± 1.23^{a}	2.83 ± 0.89^{f}	84.19 ± 1.63^{b}	1257.90 ± 18.43^{a}

**Cupcakes were processed with different concentration from potato residues: see material and methods. *Data was calculated as percentages (%). ■All of data were calculated on dry weight basis. a,b,c: Means with the same letter in the same column are not significantly different ($p > 0.05$).

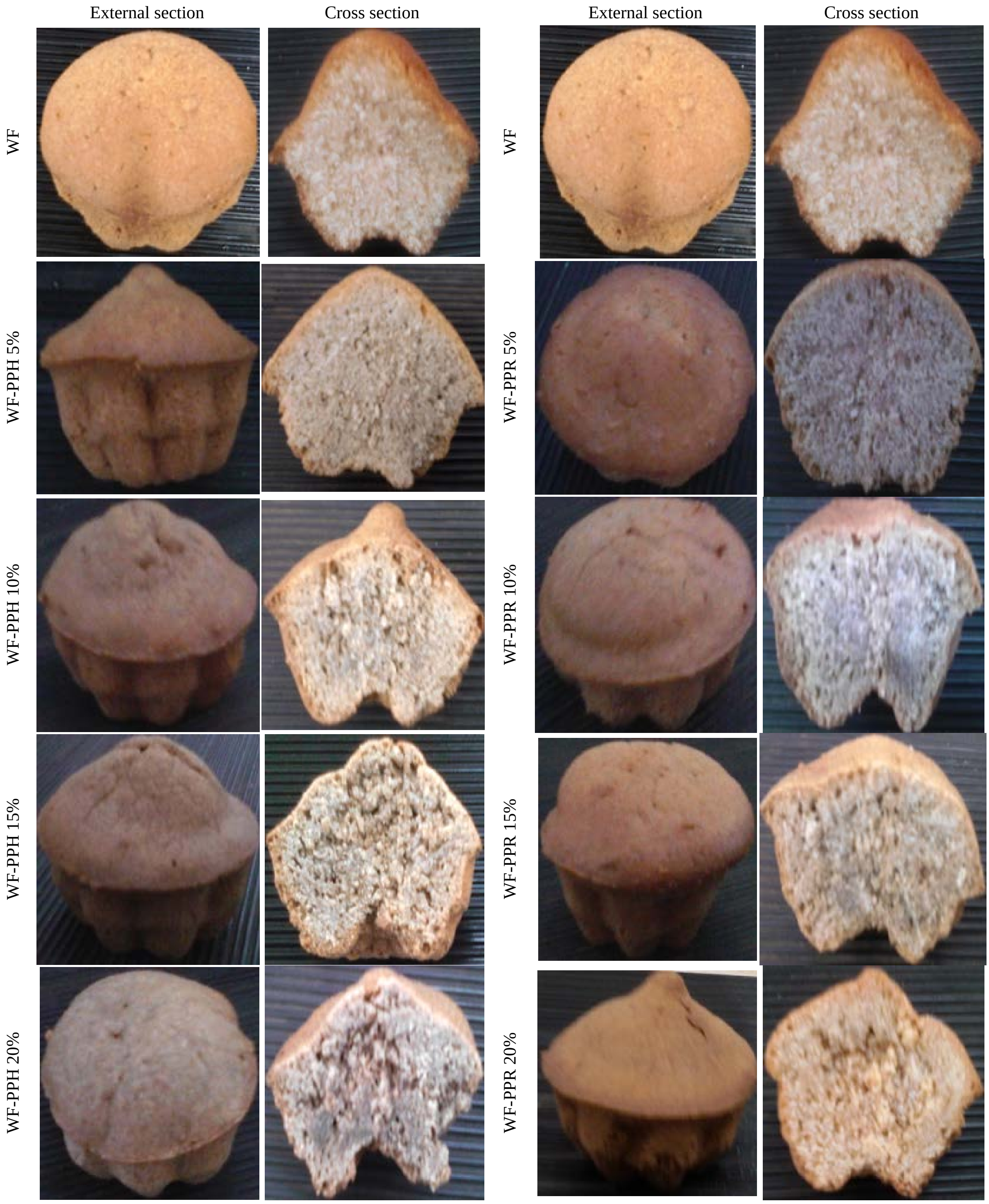


Figure 3. The effect of WF substitution by potato peels residue [Hermus (WF-PPH) and Russet (WF-PPR)] at 5% - 20% on whole cupcake morphological features as shown in external and cross sections. Cupcakes were backed at 180˚C ± 5˚C for 30 - 35 min.

3.5. Total Phenolic Compounds and Antioxidant Activity of Different WF Cupcakes Substituted with Potato Peels Residue

The TPC and relative AOA of all formulated cupcakes were investigated; data is presented in **Table 6**. No

Table 6. Total phenolic compounds and relative antioxidant activity of WF and different substituted WF cupcakes with potato peels residues.

Cupcake formulas▪	Substitution level (%)	TPC*	AOA**
WF	0	1.43 ± 0.18^{abc}	0.55 ± 0.39^{ab}
WF-PPH	5	1.78 ± 0.05^{cdef}	1.01 ± 0.23^{abc}
	10	1.43 ± 0.10^{abc}	1.22 ± 0.36^{bcd}
	15	1.51 ± 0.14^{bcd}	2.55 ± 0.42^{g}
	20	1.98 ± 0.27^{efg}	2.40 ± 0.23^{fg}
WF-PPR	5	1.41 ± 0.21^{abc}	0.37 ± 0.42^{a}
	10	1.64 ± 0.12^{bcde}	1.81 ± 0.03^{defg}
	15	2.32 ± 0.30^{g}	2.28 ± 1.02^{efg}
	20	2.06 ± 0.32f^{g}	3.44 ± 0.27^{h}

▪Cakes were processed with different concentration from potato residues: see material and methods. *Total phenolic compound were calculated as mg GAE g^{-1} dw, **Antioxidant activity was calculated as µmol TE g^{-1} dw. a,b,c: Means with the same letter in the same column are not significantly different ($p > 0.05$).

significant differences ($p > 0.05$) in TPC were observed between WF and both PP cupcakes at 5% - 10%. In contrast, significant differences ($p < 0.05$) were found between WF and both PP cupcakes at 15% and 20%; except WF-PPH 15%. Arguably, increasing of substitution level caused increasing in TPC especially from PPR. Afterwards, WF-PPR 15% cupcake recorded the highest TPC content; nevertheless the WF-PPR 5% cupcake was the lowest TPC content to be 2.32 and 1.41 mg GAE g^{-1} dw, respectively. Not only, WF-PPR cupcakes at higher concentrations listed the highest TPC content, but also they recorded the highest AOA compared with other cupcakes. Furthermore, the WF-PPR 20% cupcake recorded higher AOA than different cupcakes followed by WF-PPH 15% cupcake to be 3.44 and 2.55 µmol TE g^{-1} dw, respectively. Surely, significant differences ($p < 0.05$) were found between WF cupcake and all substitution levels of both PP residue at 15% and 20%. For this reason, the increasing of PP residue concentration increased AOA accordingly. The WF and PPH 5% cupcakes were lower in AOA than all cupcakes. This may be due to that increasing of phytochemicals as a result of increasing of PP residue levels. The AOA could enhance the bakery products shelf-life stability and retain the oil oxidation especially in cake products using the food processing residues. These results are in agreement with [4] [26] [46].

3.6. Physical Properties of Different WF Cupcakes Substituted with Potato Peels Residue

The physical properties of WF cupcakes substituted with potato peels residue at 5% - 20% including weight (g), volume (cm^3) and specific volume ($cm^3 \cdot g^{-1}$) were determined; data was illustrated in **Table 7**. Clearly, increasing of PP substitution level increased the weight property. As for volume and specific volume characteristics, significant differences ($p < 0.05$) were exhibited between WF and all cupcakes. Furthermore, the WF cupcake demonstrated the highest volume and specific volume to be 108.00 cm^3 and 2.62 $cm^3 \cdot g^{-1}$, respectively. Also, WF-PPR 5% cupcake was followed the WF cupcakes in specific volume, while WF-PPR 5% cupcake was followed the WF cupcake in volume. Significant differences ($p < 0.05$) in physical properties were found between WF and PP cupcakes when incorporated 5%, 10%, 15% and 20%. Accordingly, increasing the PP residue level could bind more water which increasing the weight. In contrary, increasing the PP residue level was decreased the volume and specific volume being affecting the gluten net with low strength and gas retention. These results are agreements with some previous studies [24] [28] [44] [45] [47].

3.7. Determination of Some Microbiological and Chemical Attributes of Different WF Cupcakes Substituted with Potato Peels Residue during Storage

3.7.1. Microbiological Attributes

The microbiological attributes such as TBC, CG and Y & M of the different WF cupcakes substituted with PP residue during storage at zero, fifth and eighth day at ambient temperature were examined; data was shown in **Table 8**. The TBC and Y & M increased as storage period was extended significantly ($p < 0.05$). Usually, substituted cupcakes with both PP residues were higher in TBC and Y & M than WF cupcake during storage period. WF-PPR 20% cupcake recorded the highest TBC at zero time. WF-PPH 15% and WF-PPH 20% cupcakes were higher in TBC than all cupcakes after five and eight days, respectively. On the other hand, WF cupcake was the lowest in Y & M especially during storage periods. However, CG wasn't detected in all cupcakes during storage period.

3.7.2. TBA Determination

The oxidative rancidity level is an important indicator for quality of stored foods. To assess the development of rancidity in cupcakes, the TBA was determined during storage time; data is summarized in **Table 9**. TBA was

Table 7. Physical properties of WF and different substituted WF cupcakes with potato peels residues.

Cupcake formulas▪	Substitution level (%)	Properties		
		Weight (g)	Volume (cm^3)	Specific volume ($cm^3 \cdot g^{-1}$)
WF	0	41.29 ± 0.47^{a}	108.00 ± 1.00^{e}	2.62 ± 0.01^{d}
WF-PPH	5	41.57 ± 0.82^{b}	93.83 ± 4.48^{cd}	2.26 ± 0.15^{c}
	10	52.95 ± 1.27^{d}	94.00 ± 2.00^{cd}	1.78 ± 0.01^{ab}
	15	53.34 ± 1.25^{d}	87.00 ± 2.00^{ab}	1.63 ± 0.07^{a}
	20	53.02 ± 3.12^{d}	94.00 ± 5.00^{cd}	1.78 ± 0.20^{ab}
WF-PPR	5	41.25 ± 0.93^{a}	94.83 ± 2.02^{cd}	2.30 ± 0.09^{c}
	10	51.64 ± 0.80^{cd}	91.67 ± 2.08^{abcd}	1.78 ± 0.03^{ab}
	15	52.23 ± 0.98^{d}	86.00 ± 2.65^{a}	1.65 ± 0.02^{a}
	20	53.30 ± 2.54^{d}	90.67 ± 4.51^{abc}	1.71 ± 0.16^{a}

▪Cakes were processed with different substitution level from potato peels residue: see material and methods. [a,b,c]: Means with the same letter in the same column are not significantly different ($p > 0.05$).

Table 8. Microbiological attributes of WF and different substituted WF cupcakes with potato peels residue during storage periods at ambient temperature.

Cupcake formula▪	Substitution level (%)	Microbiological attributes*/storage period					
		TBC [log CFU g^{-1}]			Y & M [log CFU g^{-1}]		
		0 day	5 days	8 days	0 day	5 days	8 days
WF	0	2.08 ± 0.14^{Ab}	2.76 ± 0.33^{Ba}	5.23 ± 0.03^{Ca}	nd	1.54 ± 0.26^{Aa}	3.71 ± 0.35^{Ba}
WF-PPH	5	2.12 ± 0.16^{Abc}	3.84 ± 0.36^{Bc}	5.90 ± 0.14^{Cb}	nd	1.57 ± 0.10^{Aa}	4.03 ± 0.05^{Bb}
	10	2.17 ± 0.11^{Ac}	4.07 ± 0.11^{Bde}	5.99 ± 0.07^{Cbc}	nd	1.79 ± 0.16^{Ac}	4.72 ± 0.19^{Bd}
	15	2.18 ± 0.07^{Ac}	4.14 ± 0.02^{Be}	6.09 ± 0.06^{Cc}	nd	1.83 ± 0.27^{Ad}	5.09 ± 0.21^{Bf}
	20	2.07 ± 0.11^{Ab}	3.93 ± 0.04^{Bc}	6.30 ± 0.03^{Cd}	nd	1.82 ± 0.07^{Ad}	4.98 ± 0.41^{Be}
WF-PPR	5	1.95 ± 0.12^{Aa}	3.54 ± 0.21^{Bb}	5.92 ± 0.14^{Cbc}	nd	1.62 ± 0.22^{Ab}	5.33 ± 0.05^{Bh}
	10	2.06 ± 0.09^{Ab}	3.94 ± 0.09^{Bcd}	6.00 ± 0.06^{Cc}	nd	1.86 ± 0.03^{Ade}	4.32 ± 0.14^{Bc}
	15	2.17 ± 0.14^{Ac}	4.04 ± 0.02^{Bd}	6.24 ± 0.14^{Cd}	nd	1.96 ± 0.11^{Ae}	5.04 ± 0.06^{Bg}
	20	2.22 ± 0.08^{Ac}	3.48 ± 0.14^{Bb}	6.28 ± 0.03^{Cd}	nd	1.87 ± 0.09^{Ad}	5.17 ± 0.18^{Bg}

▪Cupcakes were processed with different concentration from potato residues: see material and methods, [A,B,C]: Means with the same letter in the same row are not significantly different ($p > 0.05$). [a,b,c]: Means with the same letter in the same column are not significantly different ($p > 0.05$), [nd]: Not detected.

Table 9. Monitoring of TBA and staling of WF and different substituted WF cupcakes with potato peels residues during storage periods at ambient temperature.

Cupcake formula▪	Substitution ratio (%)	Quality indicators/storage period					
		TBA [malonaldehyde kg^{-1}]			Staling [%]		
		0 day	5 days	8 days	0 days	5 days	8 days
WF	0	0.166 ± 0.00^{Ac}	0.260 ± 0.03^{Bffg}	0.330 ± 0.03^{Cc}	329 ± 7.07^{Cab}	280 ± 2.83^{Ba}	212 ± 8.49^{Aa}
WF-PPH	5	0.164 ± 0.02^{Ac}	0.182 ± 0.03^{Bab}	0.333 ± 0.03^{Cc}	361 ± 12.73^{Bab}	355 ± 7.07^{Bbc}	330 ± 14.14^{Abc}
	10	0.182 ± 0.04^{Ad}	0.252 ± 0.03^{Be}	0.361 ± 0.04^{Cd}	381 ± 4.24^{Cb}	346 ± 8.49^{Bbc}	307 ± 12.73^{Abc}
	15	0.179 ± 0.03^{Ad}	0.208 ± 0.06^{Bbc}	0.354 ± 0.04^{Cd}	471 ± 21.21^{Cc}	436 ± 14.14^{Bcd}	385 ± 35.36^{Ac}
	20	0.182 ± 0.03^{Ad}	0.213 ± 0.03^{Bc}	0.356 ± 0.01^{Cd}	499 ± 15.56^{Cd}	433 ± 7.07^{Bcd}	407 ± 4.24^{Ad}
WF-PPR	5	0.169 ± 0.03^{Acd}	0.221 ± 0.02^{Bcd}	0.286 ± 0.07^{Cb}	397 ± 35.36^{Cbc}	377 ± 4.24^{Bbc}	360 ± 2.83^{Adcd}
	10	0.156 ± 0.05^{Abc}	0.203 ± 0.06^{Bbc}	0.255 ± 0.04^{Ca}	442 ± 39.60^{Cc}	378 ± 22.63^{Bbc}	342 ± 14.14^{Abc}
	15	0.135 ± 0.03^{Aa}	0.229 ± 0.03^{Bcd}	0.268 ± 0.04^{Cab}	466 ± 14.14^{Ccd}	408 ± 16.97^{Bc}	398 ± 11.31^{Acd}
	20	0.169 ± 0.01^{Acd}	0.226 ± 0.05^{Bcd}	0.273 ± 0.05^{Cb}	503 ± 9.90^{Cd}	481 ± 9.90^{Bd}	391 ± 12.73^{Acd}

▪Cakes were processed with different concentration from potato residues: see material and methods. ^{A,B,C}: Means with the same letter in the same row are not significantly different ($p > 0.05$). ^{a,b,c}: Means with the same letter in the same column are not significantly different ($p > 0.05$).

increased during storage period in all WF and PP cupcakes significantly. The deterioration as mg malonaldehyde kg^{-1} was higher in PPH than PPR cupcakes as observed after 8 days, significantly. The TBA indicated that WF-PPR cupcakes were the most stable during storage period. However, substitution of WF by 10% - 15% PP residue may reduce the oil rancidity and reduce the TBA, while increasing PP residues more than 15% or 20% may cause releasing of oil out from the gluten net thereby oxidized quickly by outer oxidation factors. Sharif *et al.* [48] evident that the using of rice bran oil decreased the TBA in cookies during storage periods. Also, Hafez [1] suggested that marjoram could be used to extend the shelf-life stability of cakes by decreasing the TBA during storage. However, Al-Sayed and Ahmed [24] used watermelon rinds and sharlyn melon peels extracts to retard oil oxidation in cake.

3.7.3. Staling Determination

Changing in staling of different baked cupcake during storage at ambient temperature was determined; results are shown in **Table 9**. The staling values of different cupcake formula were gradually reduced significantly ($p < 0.05$) during storage periods. The lower reduction in staling values equal a high freshness was achieved in WF and both PP 5% cupcakes. Obtained results noticed that the substituting of 15% and 20% flour by PPH or PPR recorded the highest staling values at the end of storage. Otherwise WF cupcake recorded the lowest staling at the end of storage to be 212%. These results were asserted that WF cupcake was exhibited the best staling result, followed by substituted cupcakes with PP at 5% or 10%. However, the best of our knowledge, Al-Sayed and Ahmed [24] outlined that the using of watermelon and sharlyn lemon peel powders retard significantly staling of cakes compared with control cakes.

4. Conclusion

A successful and innovative formulation of cupcake production with both PP residues was developed. The WF-PP cupcakes at different substituted levels recorded lower energy value than WF cupcakes. The substitutions of WF with both PP at 5% and 10% did not influence the thermo-mechanical and rheological properties drastically. Cupcake formulas with partial substitution of flour with 5% - 15% PPH or PPR had more natural phenolics as compared with WF cupcakes. The PPH and PPR are providing AOA to increase the shelf-life stability, reduce oil rancidity and improve staling. Substitution of WF by 5% - 15% is recommended to produce an acceptable cupcake by consumers. Adding more than 15% PP residue couldn't be applicable regarding its negative effects on cupcake characteristics. However, it could be recommended that using of PPH and PPR should be encouraged the food industries to utilize local raw materials economically into cupcake to produce low calories as functional food products.

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