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Production of biscuits by substitution with different ratios of yellow pea flour

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ABSTRACT

To promote the commercialization of yellow pea flour (YPF) due to its nutritional benefits. Four biscuits with different YPF ratio (10%–50%) were conducted to explore the optimal addition percentage. The effects of YPF on the rheological and baking performance of biscuits were performed. The results showed that the substitution ratio of YPF and milling methods had a critical impact on the rheological properties of dough. The dough stability decreased gradually while a softening degree increased with YPF ratio increased. In a term of biscuits, the dimensions of length (L), width (W), thickness (T) and color (L*) of biscuits reduced as YPF addition ratio increased, while colors (a* and b*) and hardness apparently increased. In addition, milling methods had a great influence on the texture and sensory evaluation of four biscuits. The dimensions and color parameters of biscuits from fine flours were larger than that from coarse flours, whereas hardness from fine flours was relatively softer, indicating flour with fine particle size could accelerate the extension and expansion of dough network, and improve Maillard reaction during baking. The highest sensory score for short and tough biscuits was obtained given at YPF ratio of 30% without compromising the qualities of biscuits.

1. Introduction

Biscuits are becoming an increasingly popular bakery food in developing countries due to its several attractive features, such as desirable flavor and relatively long shelf life [1]. However, the negative effects of over-consumption, such as obesity caused by high sugars and oil consumption, discouraged potential consumers [2]. Exploring the desirable low-calorie candidate as a bakery ingredient without compromising the quality of end products is highly required [3]. Pulse crop, which highly consists of fiber and essential vitamins [4], minerals [5], lysine [6,7] and antioxidants [8], could have the potential to be used for bakery products.

Given the healthy function of pulse for consumers [6,9–11], wheat flour (WF) blended with pulse-derived powder for food production has been studied recently. The addition of germinated soybean flour into WF slightly changed the Farinograph properties of dough and improved the overall bread flavor [12]. Noodles produced by adding 20% YPF exhibited favorable taste [13]. Moreover, the previous studies showed that bakery-quality had a great relationship with flour type [14], and flour particle size obtained from a milling process [15]. Because the reduction procedure of endosperm directly affects the composition of flour, determining functional properties of ingredient [16], which is consistent with other findings that the ratio of cracker stack height to dough weight increased as flour particle size decreased [17]. Extrusion was also used in a modification of starch and protein of YPF to improve the quality of end products [18]. In addition, hot-water treatment with an organic acid was carried out to alter the rheological property of pea flour [19]. However, complicated procedures applied during YPF modification are unfeasible for its commercialization, the urgent step is to find the suitable bakery product for YPF utilization.

Researches were found that YPF had high emulsion properties (water and oil holding capacity) as compared with soybean flour [20,21]. Therefore, YPF, which is gluten-free, could be a novel ingredient for biscuits or cookies production. The objective of the presented study was to evaluate the effect of YPF ratio (10%–50%) on the rheological properties of blended flour and baking performances of four biscuits.

2. Materials and methods

2.1. Materials

Yellow pea roller fine flour (YPRF), yellow pea roller coarse flour (YPRC), yellow pea pin fine flour (YPPF), and yellow pea pin coarse flour (YPPC) were provided by Canadian International Grains Institute. Purple Lida cookie four was kindly obtained from Tianjin Lijin Grain and Oil Co. Ltd., Tianjin, China, and used as control. The basic proximates of raw materials were summarized in Table. 1. All the experiments were performed in three replicates.

2.2. Flour characteristics

The moisture, ash and protein contents were determined according to AACC method 44-15A, 08-12, and AACCI method 39-11.01, respectively.

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Table 1
Basic proximates of samples.

Sample	Moisture (%)	Ash (%, db[1])	Protein (%, db[1])	Starch damage (UCD)	Particle size (μm)	SRC[2] (%)			
						Water	SC[3]	Sucrose	Lactic acid
Control	10.65 ± 0.03^{d}	0.65 ± 0.01^{a}	9.9 ± 0.3^{a}	17.9 ± 0.4^{a}	30.5	37.3	50.5	63.0	68.2
YPRF	9.63 ± 0.11^{c}	2.71 ± 0.04^{b}	23.9 ± 0.4^{c}	34.6 ± 0.2^{d}	48.7	45.7	68.7	72.3	51.1
YPRC	8.89 ± 0.09^{b}	2.79 ± 0.02^{bc}	22.1 ± 0.3^{b}	31.4 ± 0.5^{c}	71.4	42.9	68.4	76.1	48.6
YPPF	8.53 ± 0.05^{a}	2.73 ± 0.03^{b}	25.0 ± 0.5^{d}	28.9 ± 0.7^{b}	42.9	43.4	62.6	67.0	51.8
YPPC	9.30 ± 0.07^{c}	2.80 ± 0.02^{c}	23.5 ± 0.2^{c}	27.4 ± 0.9^{b}	83.0	47.7	63.7	72.6	48.9

Note: In each column, means with different letters were significantly different ($P < 0.05$).
[1] Data is on a dry basis and reported by means from three replicates.
[2] SRC: Solvent Retention Capacity.
[3] SC: Sodium Carbonate.

Starch damage was assayed basing on AACCI Method 76-31.01 with Chopin SDmatic (Chopin Technologies Ltd., Paris, France). The distribution of particle size was determined to refer to Chinese standard GBT5507-2008. Solvent Retention Capacity (SRC) was measured according to AACC 56-11. Farinograph was performed in a 300-g Brabender Farinograph (Brabender OHG, Duisburg, Germany) following AACC method 54-21, and Alveograph was performed according to AACC method 54-30.02.

2.3. Formula of cookies

2.3.1. Short biscuit

1) Designed amount of sugar powder, 0.6 g of sodium bicarbonate, 0.3 g of ammonium bicarbonate, 0.3 g of salt, 4.6 g of caramel, and 29.1 g of water were poured into a CS-B5A blender (Guangzhou Nanyu Electromechanical Equipment Co., Ltd., Guangzhou, China), and followed by adding 17 g of eggs and 11.88 g of oil.

2) Stir the mixed ingredients into an emulsion using a mixer at the fastest speed, and then lower the speed. Pour the prepared 100 g flour into a blender to form a proper dough within 1 min, and press the dough into sheet directly.

3) Fold and press the dough sheet repeatedly about 10 times until 2 mm thickness by using the DMT-5 household noodle machine (Shandong Fuxing Machinery Co., Ltd., Shandong, China).

4) Place the pressed dough sheet on a baking tray and mold them into a fixed shape by hand (length 5 cm, width 3 cm). Remove the excess material and put them into a rotary JKLZ-4 oven (Beijing Dongfujiuheng Instrument Technology Co., Ltd., Beijing, China) with the surface temperature of 200 °C and bottom temperature of 180 °C for 10 min.

2.3.2. Tough biscuit

1) Weigh the designed amount of sugar powder, 0.7 g of sodium bicarbonate, 0.4 g of ammonium bicarbonate, 0.4 g of salt, 4.0 g of caramel, and 29.1 g of water into a CS-B5A blender.

2) Stir the ingredients into an emulsion with mixer at the fastest speed, then lower the speed. Pour the prepared 100 g flour into a blender and add 11.88 g oil to form the dough. To reduce the tension and viscosity of dough, rest it for 15 min.

3) Fold and press the dough sheet repeatedly about 10 times until 2 mm thickness.

4) Place the dough sheet on a baking tray and shaped it into a fixed mold by hand (length 5 cm, width 3 cm). Remove the excess material and put them into a rotary JKLZ-4 oven with a temperature of 205 °C for 10 min.

2.3.3. Soda cracker

1) Pour 135 g flour into a solution (2 g of fresh yeast dissolved in 65 mL warm water), and mix them by using Hobart Legacy HL200-1 (Hobart Corporation, Troy, USA) at a slow speed for 4 min to form a dough.
2) Place prepared dough in a plastic box, then store in a conditioning chamber with a temperature of 28 °C and relative humidity of 70% for 5 h.
3) adding extra 135 g flour, 40.5 g of oil, 1.1 g of caramel, 12.5 g of milk powder, 1.5 g of refined salt, 1.0 g of $NaHCO_3$, 0.7 g of NH_4HCO_3 and 30 mL of warm water, and stir them at a slow speed for 5 min.
4) Put the dough in the conditioning chamber for 4 h under the same conditions.
5) Add 4.2 g refined salt and 21 g grease to 30 g flour, and mix them evenly to form pastry.
6) Fold the dough to form several layers using DMT-5 household noodle machine. Place the pressed dough on a baking sheet and shape it by hand with a pastry mold. Remove the excess material and place them in a rotary oven at 220 °C for 8 min.

2.3.4. Sugar cookie

1) Mix shortening, 65 g of sugar, 1.05 g of salt and 1.25 g of sodium bicarbonate using Hobart Legacy HL200–1 at low speed for 3 min.
2) Add 16.5 g glucose solution and a moderate amount of distilled water simultaneously, scrape and mix for 1 min. Then add flour to mix for 2 min.
3) The dough is gently scraped from the bowl and divided into 6 portions on a greased baking sheet. Smooth the dough by hand with a steel band and shape 2 times with roller in opposite direction. Press the dough sheets repeatedly about 10 times until 6 mm thickness.
4) Weigh the dough and set up the temperature at 205 °C for 10 min.

2.4. Qualities of biscuits

2.4.1. Size, color, and texture of biscuits

The diameter (D) and L, W and T of four biscuits above were determined using Digital Caliper (TESA Technology Co., Ltd., Renens, Switzerland). The colors were assayed by SMY-2000 colorimeter (Beijing Shengming Technology Development Co., Ltd., Beijing, China), Hunter values of L*, a*, and b* were reported. The texture of biscuits was determined by using TA. XT Plus Texture Analyzer (Stable Micro System, Godalming, United Kingdom). The parameters used for testing were: triggering force (5 g), descending distance (4 mm), the pre-test speed (5 mm/s), test speed (1 mm/s), and post-test speed (10 mm/s).

2.4.2. Sensory evaluation

The sensory evaluation criteria of four biscuits above were reported according to reference [22].

2.5. Data analysis

Data were analyzed using Origin Pro (version 8.5, Northampton, Massachusetts, USA). Differences among the values were analyzed using a one-way analysis of variance (ANOVA). Mean comparisons were performed using Tukey adjustment at $P < 0.05$.

3. Results and discussion

3.1. Rheological property

To evaluate the effect of YPF addition on the rheological properties of dough, the Farinograph performances of blended flours were examined (Table 2). The substitution of YPF had a significant influence on water absorption (WA) of dough. The highest WA for YPRF, YPRC, YPPF, and YPPC were obtained at a ratio of 20%, 30%, 20%, and 10%, respectively. It is likely attributed to the increment of total soluble protein and damaged starch [23,24]. The changes in Farinogragh properties caused by YPF addition were also possibly due to the compositional differences resulting in various reactions during dough formation. The cross-linking between protein and starch was initially hydrated and then developed dough network [25], the lack of glutenin in YPF could result in a reduction of elasticity and extensibility of dough. Moreover, dough development time (DDT) of flours substituted by YPPF and YPPC was significantly extended 1.28 min as compared with control, while that of YPRF decreased from 1.28 min to 0.48 min, which indicated that the milling methods had a great impact on the dough properties.

The stable time of blended flours decreased significantly, and the dough softening degree increased, which was due to the space of gluten network was dominated by other non-protein components causing dough resistance weaker after adding YPF. These results were consistent with other findings that strong-gluten flours were characterized by a long development time, high stability with a small degree of softening, while poor flours were weak quickly with low stability [12,26].

The elasticity and extensibility of dough can be reflected by Alveograph. P and G reflect the strength and air holding capability of the dough network. Table 3 showed that the *P*-value of blended dough decreased as compared with control. The decrease in L, G, and W values from mixed dough demonstrated the gluten network was weak during kneading. The energy, required to handle the dough, decreased at the same time. These changes are likely attributed to an intense incompatibility between components from YPF and that from wheat flour during dough formation, which is an agreement with that the substitution of wheat protein by soy protein resulting in softening and less malleable of dough [27]. In addition, YPF mainly contains vegetable protein, P/L was larger than 1 (Table 3), indicating that the flexibility of dough became greater than extensibility.

Table 2
Farinograph property of flours with different substitution ratio of YPF.

Sample	Ratio (%)	Water absorption (%)	Development (min)	Stability (min)	Softening (FU)	FQN (FU)
Control	0	57.4	1.28	9.26	58	44
YPRF	10	58.5	1.09	4.38	66	52
	20	58.5	0.52	3.52	80	44
	30	57.7	0.54	1.11	138	17
	40	57.3	0.54	1.02	155	17
	50	56.6	0.48	0.49	176	12
YPRC	10	57.7	1.30	5.53	53	69
	20	58.3	1.01	4.21	65	52
	30	59.3	1.02	4.21	95	52
	40	59.1	3.40	2.24	145	51
	50	59.0	3.53	2.02	183	56
YPPF	10	58.3	4.16	6.34	62	75
	20	58.5	3.18	4.38	70	54
	30	57.9	3.25	4.20	123	51
	40	57.8	3.33	2.20	158	52
	50	56.3	4.01	4.46	219	58
YPPC	10	59.1	4.08	7.21	47	86
	20	58.6	2.55	4.31	61	53
	30	58.8	3.18	3.01	113	51
	40	58.3	3.31	2.10	162	53
	50	57.8	4.23	2.11	202	57

Note: The experiment was conducted once.

Table 3
Alveograph property of flours with different substitution ratio of YPF.

Sample	Ratio (%)	P (mm H_2O)	L (mm)	G	P/L	W (mJ)
Control	0	104	52	16.0	2.0	199
YPRF	10	68	71	18.7	1.0	159
	20	61	44	14.8	1.4	98
	30	63	26	11.4	2.4	70
	40	62	28	11.7	2.2	69
	50	63	16	8.8	4.1	46
YPRC	10	79	50	15.7	1.6	142
	20	79	28	11.8	2.8	91
	30	95	18	9.5	5.3	74
	40	85	21	10.2	4.1	71
	50	76	14	8.3	5.4	46
YPPF	10	71	45	15.0	1.6	103
	20	74	39	13.9	1.9	86
	30	75	29	12.0	2.6	72
	40	84	20	10.1	4.1	63
	50	79	19	9.8	4.0	56
YPPC	10	64	39	14.0	1.6	82
	20	62	23	10.7	2.7	55
	30	56	22	10.4	2.6	44
	40	71	17	9.1	4.2	49
	50	74	14	8.3	5.3	42

Note: The P, L, G, and W were tenacity (dough height × 1.1), extensibility (length), expansion of volume ($G = 2.226\ L^{1/2}$), work input, respectively. The experiment was conducted once.

3.2. Size of biscuits

The effect of YPF addition on the sizes of biscuits was summarized in Table 4. The sizes of biscuits decreased slightly as YPF ratio increased from 10% to 50%. Short biscuit, tough biscuit and soda cracker from YPRF and YPPF were comparatively wider and thicker than that from YPRC and YPPC, which indicated that flour with smaller particle size had greater extensibility. The T and D values of sugar cookie from YPPF were slightly bigger than that from YPRF, which is consistent with the previous study that milling method determining in differences of particle size had a significant influence on biscuit dimensions [14]. The W and T of short biscuits from YPF were smaller than that of tough biscuits, the L and W of soda crackers were bigger than both short and tough biscuits. The increment of extensibility for soda cracker and tough biscuit could be due to the difference of formula at some extent. Such as the addition of sodium bicarbonate, ammonium bicarbonate, and fresh yeast could accelerate the formation of gluten network promoting the dough expansion. Among the flour types of biscuits, the L, W, and T of soda cracker were considerably larger than that of short and tough biscuits, which is likely attributed to the process of fermentation promoted the development and extension of gluten network efficiently.

3.3. Color of biscuits

The color of biscuits was reported by Hunter L*, a*, and b* values corresponding to lightness, redness, and yellowness, respectively. Color plays an important role in attracting consumers [13]. The crust of control exhibited lighter (L*) and lesser yellow (b*) than blended biscuits, indicating that a redder and yellower surface was obtained from YPF substitution. As YPF addition ratio increased from 10% to 50%, the L* of biscuits gradually decreased, while a* and b* increased significantly (Table 5), which is consistent with the conclusion that the addition of chickpea flour into bread gave darker crust [25]. These changes were possibly attributed to the Maillard reaction during baking. The b* of biscuits increased with the increment of addition ratio, which was particularly attributed to the oxidation of internal pigment components of YPF, such as carotenoids and lutein pigments. An increase in a* of biscuits had relations with the reaction of reducing sugars and amino acids. The L*, a*, and b* of biscuits from YPRF and YPPF were remarkably higher than that from YPRC and YPPC, which suggested that

Table 4
Size of biscuits with different substitution ratio of YPF.

Sample	Ratio	Short Biscuit (mm)			Tough Biscuit (mm)			Soda Cracker (mm)			Sugar Cookie (mm)	
	(%)	L	W	T	L	W	T	L	W	T	T	D
Control	0	54.36 ± 0.00^{e}	31.79 ± 0.01^{e}	3.09 ± 0.01^{e}	54.41 ± 0.00^{f}	31.87 ± 0.01^{e}	3.13 ± 0.01^{f}	55.70 ± 0.01^{d}	33.11 ± 0.00^{e}	3.32 ± 0.01^{g}	8.19 ± 0.01^{d}	72.28 ± 0.01^{e}
	10	54.33 ± 0.01^{de}	31.75 ± 0.00^{d}	3.05 ± 0.01^{e}	54.38 ± 0.01^{e}	31.86 ± 0.00^{de}	3.10 ± 0.02^{f}	55.68 ± 0.01^{d}	33.08 ± 0.01^{e}	3.28 ± 0.01^{g}	8.15 ± 0.00^{c}	72.20 ± 0.00^{d}
	20	54.31 ± 0.01^{d}	31.74 ± 0.01^{cd}	3.01 ± 0.00^{d}	54.37 ± 0.01^{e}	31.85 ± 0.01^{de}	3.10 ± 0.01^{f}	55.61 ± 0.00^{c}	33.00 ± 0.01^{d}	3.18 ± 0.01^{f}	8.12 ± 0.01^{b}	72.11 ± 0.01^{c}
YPRF	30	54.30 ± 0.00^{d}	31.71 ± 0.00^{c}	2.99 ± 0.01^{cd}	54.24 ± 0.00^{c}	31.80 ± 0.01^{d}	3.01 ± 0.01^{d}	55.55 ± 0.01^{c}	32.89 ± 0.00^{b}	3.11 ± 0.00^{e}	8.11 ± 0.01^{b}	72.10 ± 0.01^{c}
	40	54.25 ± 0.01^{c}	31.72 ± 0.01^{c}	2.98 ± 0.01^{cd}	54.23 ± 0.01^{c}	31.74 ± 0.00^{c}	2.99 ± 0.00^{d}	55.56 ± 0.01^{c}	32.88 ± 0.01^{b}	2.95 ± 0.01^{c}	8.10 ± 0.00^{b}	72.03 ± 0.01^{b}
	50	54.21 ± 0.01^{b}	31.63 ± 0.01^{b}	2.96 ± 0.00^{c}	54.19 ± 0.01^{b}	31.75 ± 0.01^{c}	2.99 ± 0.01^{d}	55.41 ± 0.00^{b}	32.87 ± 0.01^{b}	2.94 ± 0.01^{c}	8.08 ± 0.01^{b}	72.01 ± 0.01^{b}
	10	54.30 ± 0.00^{d}	31.71 ± 0.01^{c}	3.01 ± 0.01^{d}	54.35 ± 0.00^{e}	31.82 ± 0.02^{d}	3.06 ± 0.01^{ef}	55.50 ± 0.01^{c}	32.87 ± 0.01^{b}	3.00 ± 0.00^{c}	8.11 ± 0.01^{b}	72.16 ± 0.01^{c}
	20	54.29 ± 0.01^{d}	31.70 ± 0.00^{c}	2.96 ± 0.01^{c}	54.35 ± 0.01^{e}	31.81 ± 0.01^{d}	3.04 ± 0.00^{e}	55.38 ± 0.01^{b}	32.86 ± 0.00^{b}	2.91 ± 0.01^{b}	8.10 ± 0.01^{b}	72.13 ± 0.00^{c}
YPRC	30	54.20 ± 0.00^{b}	31.63 ± 0.01^{b}	2.93 ± 0.00^{b}	54.28 ± 0.01^{d}	31.70 ± 0.00^{c}	2.92 ± 0.01^{c}	55.36 ± 0.00^{ab}	32.87 ± 0.01^{b}	2.90 ± 0.01^{b}	8.02 ± 0.00^{a}	72.11 ± 0.01^{c}
	40	54.11 ± 0.01^{a}	31.59 ± 0.00^{b}	2.90 ± 0.01^{b}	54.29 ± 0.00^{d}	31.61 ± 0.01^{b}	2.83 ± 0.01^{b}	55.31 ± 0.01^{a}	32.80 ± 0.01^{a}	2.87 ± 0.00^{b}	7.99 ± 0.01^{a}	72.06 ± 0.01^{b}
	50	54.13 ± 0.01^{a}	31.60 ± 0.01^{b}	2.90 ± 0.01^{b}	54.16 ± 0.01^{b}	31.49 ± 0.01^{a}	2.84 ± 0.01^{b}	55.30 ± 0.01^{a}	32.80 ± 0.00^{a}	2.81 ± 0.01^{a}	7.99 ± 0.01^{a}	71.88 ± 0.01^{a}
	10	54.33 ± 0.00^{de}	31.77 ± 0.01^{d}	3.07 ± 0.00^{e}	54.40 ± 0.01^{ef}	31.87 ± 0.00^{e}	3.12 ± 0.01^{f}	55.70 ± 0.01^{d}	33.09 ± 0.01^{e}	3.31 ± 0.01^{g}	8.18 ± 0.00^{d}	72.24 ± 0.01^{d}
	20	54.26 ± 0.01^{c}	31.69 ± 0.00^{c}	3.06 ± 0.01^{e}	54.39 ± 0.00^{ef}	31.79 ± 0.01^{d}	3.00 ± 0.00^{d}	55.69 ± 0.00^{d}	33.07 ± 0.01^{e}	3.30 ± 0.01^{g}	8.17 ± 0.01^{d}	72.21 ± 0.01^{d}
YPPF	30	54.25 ± 0.01^{c}	31.61 ± 0.01^{b}	2.99 ± 0.01^{cd}	54.24 ± 0.01^{c}	31.63 ± 0.01^{b}	2.93 ± 0.01^{c}	55.60 ± 0.01^{c}	32.93 ± 0.00^{c}	3.19 ± 0.00^{f}	8.16 ± 0.01^{cd}	72.21 ± 0.00^{d}
	40	54.17 ± 0.02^{b}	31.61 ± 0.01^{b}	3.00 ± 0.00^{d}	54.25 ± 0.00^{c}	31.63 ± 0.00^{b}	2.91 ± 0.01^{c}	55.58 ± 0.01^{c}	32.90 ± 0.01^{bc}	3.17 ± 0.01^{f}	8.15 ± 0.01^{c}	72.20 ± 0.01^{d}
	50	54.16 ± 0.00^{ab}	31.53 ± 0.01^{a}	2.96 ± 0.01^{c}	54.16 ± 0.01^{b}	31.61 ± 0.01^{b}	2.79 ± 0.01^{a}	55.44 ± 0.00^{b}	32.74 ± 0.01^{a}	3.04 ± 0.01^{d}	8.13 ± 0.00^{bc}	72.18 ± 0.01^{cd}
	10	54.32 ± 0.01^{de}	31.74 ± 0.00^{cd}	3.03 ± 0.01^{de}	54.38 ± 0.01^{e}	31.84 ± 0.01^{de}	3.09 ± 0.01^{f}	55.57 ± 0.01^{c}	33.03 ± 0.01^{d}	3.07 ± 0.01^{d}	8.14 ± 0.01^{c}	72.20 ± 0.01^{d}
	20	54.30 ± 0.00^{d}	31.71 ± 0.01^{c}	3.01 ± 0.01^{d}	54.39 ± 0.00^{ef}	31.80 ± 0.01^{d}	3.08 ± 0.01^{ef}	55.44 ± 0.01^{b}	33.01 ± 0.00^{d}	3.04 ± 0.01^{d}	8.13 ± 0.01^{bc}	72.11 ± 0.01^{c}
YPPC	30	54.19 ± 0.01^{b}	31.62 ± 0.01^{b}	2.91 ± 0.00^{b}	54.23 ± 0.01^{c}	31.79 ± 0.00^{d}	3.08 ± 0.00^{ef}	55.43 ± 0.01^{b}	33.23 ± 0.01^{f}	2.99 ± 0.01^{c}	8.11 ± 0.01^{b}	72.11 ± 0.01^{c}
	40	54.18 ± 0.01^{b}	31.61 ± 0.00^{b}	2.86 ± 0.01^{a}	54.19 ± 0.01^{b}	31.79 ± 0.01^{d}	3.03 ± 0.01^{de}	55.42 ± 0.00^{b}	33.22 ± 0.01^{f}	2.91 ± 0.00^{b}	8.10 ± 0.01^{b}	72.06 ± 0.01^{b}
	50	54.19 ± 0.00^{b}	31.59 ± 0.01^{b}	2.85 ± 0.01^{a}	54.03 ± 0.00^{a}	31.63 ± 0.02^{b}	2.99 ± 0.01^{d}	55.39 ± 0.01^{b}	33.20 ± 0.01^{f}	2.89 ± 0.01^{b}	8.02 ± 0.00^{a}	72.05 ± 0.02^{b}

Note: Means in the same column with different letters are significantly different ($P < 0.05$). Data was reported from duplicates.

Table 5
Color of four biscuits.

Sample	Ratio	Short Biscuit			Tough Biscuit			Soda Cracker			Sugar Cookie		
	(%)	L*	a*	b*	L*	a*	b*	L*	a*	b*	L*	a*	b*
Control	0	75.1 ± 0.2^{e}	4.49 ± 0.3^{a}	30.6 ± 0.1^{a}	77.9 ± 0.0^{g}	4.17 ± 0.2^{a}	29.6 ± 0.0^{a}	79.1 ± 0.0^{g}	4.21 ± 0.2^{a}	28.5 ± 0.1^{a}	66.3 ± 0.0^{j}	5.60 ± 0.3^{a}	35.7 ± 0.2^{a}
	10	74.9 ± 0.1^{e}	7.82 ± 0.1^{f}	38.8 ± 0.2^{e}	77.7 ± 0.2^{g}	7.39 ± 0.0^{f}	36.8 ± 0.1^{e}	78.9 ± 0.0^{g}	7.30 ± 0.2^{f}	35.7 ± 0.0^{f}	66.4 ± 0.2^{j}	8.82 ± 0.0^{f}	52.6 ± 0.2^{h}
	20	74.8 ± 0.0^{e}	7.83 ± 0.1^{f}	39.0 ± 0.1^{e}	77.6 ± 0.1^{fg}	7.42 ± 0.0^{f}	37.0 ± 0.1^{e}	78.6 ± 0.3^{fg}	7.31 ± 0.1^{f}	36.0 ± 0.1^{g}	66.3 ± 0.1^{j}	8.83 ± 0.0^{f}	52.8 ± 0.1^{h}
YPRF	30	74.5 ± 0.0^{de}	7.85 ± 0.1^{fg}	39.1 ± 0.1^{e}	77.5 ± 0.3^{fg}	7.43 ± 0.0^{fg}	37.2 ± 0.0^{ef}	78.5 ± 0.1^{f}	7.33 ± 0.1^{fg}	36.2 ± 0.1^{gh}	65.9 ± 0.3^{ij}	8.84 ± 0.0^{fg}	52.9 ± 0.2^{hi}
	40	74.4 ± 0.0^{d}	7.88 ± 0.2^{g}	39.5 ± 0.0^{f}	77.3 ± 0.2^{fg}	7.46 ± 0.0^{g}	37.3 ± 0.1^{f}	78.3 ± 0.2^{f}	7.35 ± 0.3^{gh}	36.4 ± 0.1^{h}	65.8 ± 0.2^{i}	8.88 ± 0.0^{g}	53.2 ± 0.1^{i}
	50	74.1 ± 0.3^{d}	7.92 ± 0.2^{g}	39.6 ± 0.1^{f}	77.2 ± 0.1^{f}	7.50 ± 0.0^{h}	37.5 ± 0.1^{fg}	78.2 ± 0.2^{f}	7.38 ± 0.1^{h}	36.5 ± 0.0^{h}	65.2 ± 0.0^{h}	8.89 ± 0.0^{g}	53.3 ± 0.1^{i}
	10	73.2 ± 0.1^{c}	7.16 ± 0.0^{b}	36.7 ± 0.2^{b}	75.3 ± 0.1^{c}	6.86 ± 0.2^{b}	34.8 ± 0.1^{b}	77.1 ± 0.2^{d}	6.75 ± 0.1^{b}	33.3 ± 0.1^{b}	63.5 ± 0.2^{de}	6.15 ± 0.2^{b}	41.8 ± 0.1^{e}
	20	73.1 ± 0.1^{c}	7.17 ± 0.1^{b}	36.9 ± 0.2^{b}	75.2 ± 0.1^{c}	6.87 ± 0.1^{b}	34.9 ± 0.2^{b}	76.9 ± 0.0^{d}	6.77 ± 0.1^{b}	33.6 ± 0.3^{bc}	63.2 ± 0.1^{d}	6.17 ± 0.1^{b}	41.9 ± 0.1^{e}
YPRC	30	72.7 ± 0.3^{bc}	7.21 ± 0.2^{c}	37.1 ± 0.2^{b}	74.9 ± 0.3^{bc}	6.90 ± 0.2^{bc}	35.2 ± 0.1^{bc}	76.8 ± 0.3^{cd}	6.78 ± 0.3^{bc}	33.8 ± 0.1^{c}	62.9 ± 0.4^{cd}	6.23 ± 0.2^{c}	42.1 ± 0.2^{ef}
	40	72.6 ± 0.1^{b}	7.23 ± 0.1^{c}	37.5 ± 0.1^{c}	74.8 ± 0.3^{b}	6.93 ± 0.1^{c}	35.3 ± 0.0^{c}	76.7 ± 0.1^{c}	6.80 ± 0.1^{c}	33.9 ± 0.1^{c}	62.7 ± 0.2^{c}	6.24 ± 0.1^{c}	42.5 ± 0.2^{f}
	50	72.5 ± 0.1^{b}	7.26 ± 0.3^{c}	37.6 ± 0.1^{c}	74.5 ± 0.2^{b}	6.91 ± 0.0^{c}	35.5 ± 0.2^{cd}	76.4 ± 0.1^{c}	6.82 ± 0.1^{c}	34.1 ± 0.1^{c}	62.6 ± 0.1^{c}	6.26 ± 0.1^{c}	42.6 ± 0.1^{f}
	10	74.8 ± 0.0^{e}	8.47 ± 0.3^{h}	39.1 ± 0.2^{e}	76.9 ± 0.2^{ef}	8.17 ± 0.3^{i}	37.0 ± 0.1^{e}	78.6 ± 0.3^{fg}	8.11 ± 0.0^{i}	35.1 ± 0.2^{e}	65.1 ± 0.2^{gh}	9.48 ± 0.0^{h}	43.1 ± 0.1^{g}
	20	74.6 ± 0.1^{de}	8.49 ± 0.2^{h}	39.3 ± 0.2^{ef}	76.6 ± 0.3^{e}	8.18 ± 0.2^{i}	37.2 ± 0.0^{e}	78.4 ± 0.1^{f}	8.12 ± 0.0^{i}	35.2 ± 0.3^{e}	64.7 ± 0.2^{g}	9.49 ± 0.0^{h}	43.2 ± 0.0^{g}
YPPF	30	74.3 ± 0.0^{d}	8.51 ± 0.0^{h}	39.6 ± 0.1^{f}	76.2 ± 0.1^{de}	8.20 ± 0.1^{i}	37.6 ± 0.1^{fg}	78.3 ± 0.2^{f}	8.15 ± 0.0^{ij}	35.6 ± 0.0^{f}	64.3 ± 0.1^{f}	9.51 ± 0.0^{hi}	39.6 ± 0.2^{d}
	40	74.0 ± 0.0^{d}	8.51 ± 0.1^{h}	39.8 ± 0.1^{f}	76.0 ± 0.1^{d}	8.21 ± 0.1^{i}	37.8 ± 0.1^{fg}	77.9 ± 0.2^{ef}	8.17 ± 0.0^{j}	35.8 ± 0.2^{f}	64.1 ± 0.1^{f}	9.52 ± 0.0^{hi}	39.8 ± 0.1^{d}
	50	73.9 ± 0.0^{d}	8.52 ± 0.2^{h}	39.7 ± 0.1^{f}	75.9 ± 0.0^{d}	8.25 ± 0.0^{j}	37.9 ± 0.2^{g}	77.6 ± 0.1^{e}	8.18 ± 0.0^{j}	35.9 ± 0.0^{fg}	63.8 ± 0.2^{ef}	9.54 ± 0.0^{i}	39.7 ± 0.1^{d}
	10	72.8 ± 0.2^{bc}	7.56 ± 0.2^{d}	37.9 ± 0.2^{cd}	75.2 ± 0.0^{c}	7.23 ± 0.1^{d}	35.3 ± 0.1^{c}	76.5 ± 0.0^{c}	7.06 ± 0.1^{d}	34.1 ± 0.3^{cd}	62.5 ± 0.1^{bc}	8.58 ± 0.2^{d}	37.9 ± 0.2^{b}
	20	72.7 ± 0.3^{b}	7.59 ± 0.1^{d}	38.2 ± 0.1^{d}	74.9 ± 0.1^{b}	7.24 ± 0.1^{d}	35.4 ± 0.1^{c}	75.9 ± 0.1^{b}	7.09 ± 0.2^{de}	34.4 ± 0.0^{d}	62.4 ± 0.1^{bc}	8.59 ± 0.1^{d}	38.2 ± 0.1^{b}
YPPC	30	72.2 ± 0.2^{b}	7.60 ± 0.0^{de}	38.3 ± 0.1^{d}	74.8 ± 0.1^{b}	7.26 ± 0.3^{de}	35.0 ± 0.3^{c}	75.8 ± 0.1^{ab}	7.11 ± 0.1^{e}	34.6 ± 0.2^{d}	62.1 ± 0.2^{ab}	8.61 ± 0.1^{d}	38.3 ± 0.2^{b}
	40	71.8 ± 0.1^{a}	7.62 ± 0.1^{e}	38.4 ± 0.2^{d}	74.6 ± 0.1^{b}	7.28 ± 0.1^{e}	35.8 ± 0.1^{d}	75.6 ± 0.1^{a}	7.12 ± 0.1^{e}	34.7 ± 0.3^{de}	61.8 ± 0.1^{a}	8.62 ± 0.2^{de}	38.4 ± 0.2^{bc}
	50	71.5 ± 0.2^{a}	7.63 ± 0.1^{e}	38.7 ± 0.2^{de}	74.1 ± 0.1^{a}	7.31 ± 0.2^{e}	35.9 ± 0.2^{d}	75.5 ± 0.2^{a}	7.13 ± 0.1^{e}	34.9 ± 0.0^{e}	61.7 ± 0.2^{a}	8.65 ± 0.1^{e}	38.7 ± 0.1^{c}

Note: Means in the same column with different letters are significantly different ($P < 0.05$). Data was reported from duplicates.

the finer particle size of YPF could generate darker color of biscuits. In terms of four biscuits, the rank of brightness values was: soda crackers > tough biscuits > short biscuits > sugar cookies. However, the change in values of a* and b* was apparently opposite, which reasonably indicated that the formula including addition amount of sugar, sodium bicarbonate, ammonium bicarbonate, salt, caramel, oil, and water had a significant effect on the color of biscuits.

3.4. Textural property of biscuits

The hardness of biscuits is considered as an intuitive response of mouthfeel [28]. The hardness of four biscuits was presented in Fig. 1. The hardness of four biscuits varied obviously, the rank of hardness was: sugar cookie > tough biscuits > soda cracker > short cookie. As YPF ratio increased from 10% to 50%, hardness of short biscuit, tough biscuit, and soda cracker increased gradually by 7.16%, 4.05%, 5.04%, 7.26%, respectively, which was due to the relative decreasing of gluten content in dough weakened the strength of starch-protein crosslink strength, resulting in non-swelled internal structure. Whereas there were no significant changes for sugar biscuit. The hardness of biscuits from YPRF and YPPF was slightly softer than that from YPRC and YPPC, which also indicated that particle size had a great influence on biscuits texture. Fine particle size provides more chances for ingredients to mutually combine creating more channels and air cells, and form a more foamy structure that is easier to be broken as compared with coarse [29].

3.5. Sensory evaluation of biscuits

The sensory evaluation of biscuits was listed in Table 6. The shapes of food products had a strong influence on the sensory properties and product acceptability [13]. Therefore, the same mold was used for biscuits production in the present study, except for sugar cookies. The highest sensory scores of 84.5 for short biscuit and 86.0 for tough biscuit were obtained at an addition ratio of 30%. Interestingly, the scores of short biscuits were higher than control, which indicated that YPF has the potential to be used as a functional ingredient for short biscuit [10]. However, the total scores of soda crackers decreased with the augment of YPF ratio, which is ascribed to YPF deteriorated dough network. Among four types of biscuits, the rank of a sensory score was: short biscuit > tough biscuits > sugar cookie > soda cracker, which indicated that YPF was more feasible for baking short biscuits.

Table 6
Sensory evaluation of biscuits with different substitution ratio of YPF.

Sample	Ratio	Total score			
	(%)	Short biscuit	Tough biscuit	Soda cracker	Sugar cookie
Control	0	78.0 ± 0.2[a]	73.0 ± 0.4[a]	74.0 ± 0.2[e]	75.0 ± 0.3[a]
	10	79.5 ± 0.6[b]	77.5 ± 0.7[bc]	70.5 ± 0.4[c]	79.5 ± 0.5[c]
	20	82.0 ± 0.2[d]	80.0 ± 0.5[de]	70.0 ± 0.2[c]	79.5 ± 0.4[c]
YPRF	30	82.0 ± 0.3[d]	81.0 ± 0.2[e]	71.0 ± 0.4[c]	81.0 ± 0.4[d]
	40	79.0 ± 0.8[b]	78.5 ± 0.4[c]	70.5 ± 0.6[c]	79.5 ± 0.3[c]
	50	79.0 ± 0.9[b]	76.0 ± 0.8[b]	67.5 ± 0.6[b]	78.0 ± 0.4[b]
	10	82.0 ± 0.2[d]	80.5 ± 0.2[de]	74.5 ± 0.5[ef]	80.5 ± 0.3[d]
	20	82.5 ± 0.2[de]	84.5 ± 0.6[g]	75.0 ± 0.2[f]	81.0 ± 0.5[d]
YPRC	30	84.5 ± 0.2[f]	86.0 ± 0.3[h]	74.5 ± 0.6[ef]	83.0 ± 0.4[e]
	40	83.0 ± 0.4[e]	81.0 ± 0.6[e]	73.0 ± 0.4[d]	80.0 ± 0.2[d]
	50	81.5 ± 0.2[cd]	78.5 ± 0.4[c]	71.5 ± 0.2[c]	78.0 ± 0.3[b]
	10	80.5 ± 0.5[bc]	80.0 ± 0.2[d]	76.0 ± 0.2[g]	80.0 ± 0.7[d]
	20	81.0 ± 0.3[c]	82.0 ± 0.2[f]	73.5 ± 0.6[de]	80.5 ± 0.5[d]
YPPF	30	84.5 ± 0.4[f]	84.0 ± 0.2[g]	73.0 ± 0.2[d]	78.5 ± 0.7[bc]
	40	83.5 ± 0.6[ef]	81.0 ± 0.7[e]	71.0 ± 0.5[c]	77.0 ± 0.6[b]
	50	81.0 ± 0.4[c]	78.5 ± 0.5[c]	68.5 ± 0.4[b]	74.5 ± 0.4[a]
	10	80.5 ± 0.2[bc]	80.0 ± 0.4[de]	74.0 ± 0.2[e]	79.0 ± 0.2[bc]
	20	82.5 ± 0.3[de]	82.5 ± 0.3[f]	73.0 ± 0.8[de]	81.0 ± 0.4[d]
YPPC	30	82.5 ± 0.4[de]	81.5 ± 0.7[ef]	72.0 ± 0.2[d]	79.5 ± 0.2[c]
	40	81.5 ± 0.7[cd]	79.0 ± 0.8[cd]	70.5 ± 0.2[c]	79.0 ± 0.4[c]
	50	80.5 ± 0.4[bc]	74.0 ± 0.7[a]	65.5 ± 0.4[a]	77.5 ± 0.3[b]

Note: Means in the same column with different letters are significantly different ($P < 0.05$). Data was reported from duplicates.

4. Conclusions

The substitution of YPF had a great influence on the rheological properties of dough and the baking performances of biscuits. The dough stability decreased and softening degree increased remarkably as YPF ratio increased. The size of biscuits reduced gradually, while color (a*, b*) and hardness of biscuits significantly increased with the increment of YPF ratio. Milling methods played an important role in the texture and sensory

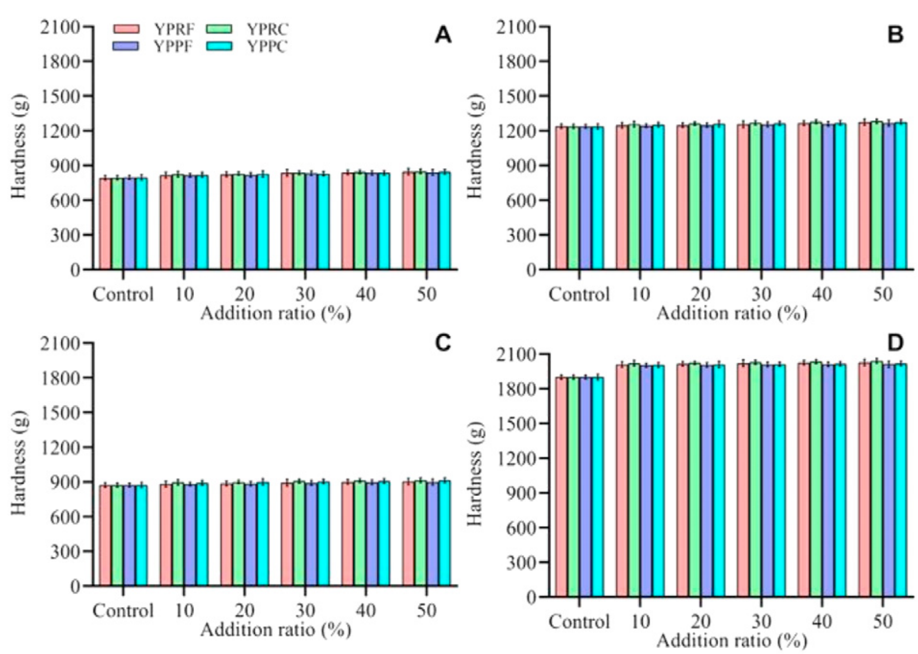

Fig. 1. Textural property of biscuits with different substitution ratio of YPF.
Note: A: short biscuit, B: tough biscuit, C: soda cracker, D: sugar cookie, data was reported from four replicates.

evaluation of four biscuits. The short and tough biscuits appeared to have the highest sensory score without compromising the qualities of biscuits at an addition ratio of 30%.

Declaration of competing interest

All the authors confidently declare that there is no conflict of interest.

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