

Physicochemical properties and *in vitro* starch digestibility of biofortified yellow maize and cowpea composite flours and biscuits

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INTRODUCTION

As part of research efforts toward achieving the second sustainable development goal (SDG) of the UN (that is, to “end hunger, achieve food security and improved nutrition and promote sustainable agriculture), we developed biscuits from biofortified yellow maize (YM) and cowpea (CP) composite flours and evaluated their physicochemical properties and *in vitro* starch digestibility. Conventionally, biscuits, being baked from white wheat flour, are energy-dense and lack sufficient protein quantity; this makes consumers that are calorie-conscious to keep off from eating them (Aggarwal *et al.*, 2016). They are also deficient in the bioactive constituents in whole grains that are beneficial to health, such as phytochemicals and dietary fiber (Irondi *et al.*, 2021). Hence, we replaced white wheat flour with composite flours of YM and CP, and evaluated their physicochemical properties and *in vitro* starch digestibility.

RESEARCH METHODOLOGY

Whole meal flours of YM (provitamin A yellow maize), CP (IT10K-837-1) and their composites were used in this study. The YM and CP flours were mixed at the proportions of 100:0; 75:25; 50:50; 25:75; 0:100 to obtain the composite flours coded YM, YMCP-1, YMCP-2, YMCP-3 and CP, respectively. White wheat flour (WT) was used as a control. Biscuits, coded YM-B, YMCP-1B, YMCP-2B, YMCP-3B, CP-B and WT-B (Fig. 1), were formulated and baked from their corresponding flours. Physicochemical analyses (pasting properties, proximate composition, starch profile) and *in vitro* starch digestibility were performed on the flours and biscuits, while the sensory attributes of the biscuits were also evaluated. The results of replicate experiments were analyzed using one-way analysis of variance and the means were compared using Duncan's multiple range test at 95% confidence level.

RESULTS AND DISCUSSION



Figure 1. Biscuits samples: CP-B, 100% cowpea biscuit; YMCP-3B, 25:75 (% w/w) yellow maize and cowpea composite biscuit; YMCP-2B, 50:50 (% w/w) yellow maize and cowpea composite biscuit; YMCP-1B, 75:25 (% w/w) yellow maize and cowpea composite biscuit; YM-B, 100% yellow maize biscuit; WT-B, 100% white wheat flour biscuit

Table 1. Pasting properties of flour samples

Flours	Peak viscosity (RVU)	Trough viscosity (RVU)	Breakdown viscosity (RVU)	Final viscosity (RVU)	Setback Viscosity (RVU)	Peak time (min)	Pasting temperature (°C)
YM	36.47±0.64 ^f	29.74±0.61 ^e	6.73±0.05 ^c	157.36±0.20 ^b	127.62±0.41 ^a	7.02±0.03 ^a	93.55±0.07 ^b
YMCP-1	27.80±0.31 ^e	27.03±0.28 ^f	0.78±0.04 ^f	48.55±1.02 ^e	21.53±0.74 ^f	6.64±0.04 ^b	95.13±0.11 ^a
YMCP-2	64.18±0.22 ^d	62.95±0.18 ^b	1.23±0.04 ^e	175.43±0.81 ^a	112.98±0.08 ^b	5.31±0.06 ^d	87.15±0.21 ^d
YMCP-3	65.52±0.03 ^c	61.37±0.07 ^c	4.15±0.10 ^d	154.50±0.24 ^c	93.13±0.17 ^c	5.03±0.04 ^e	84.78±0.04 ^e
CP	82.83±0.36 ^b	58.53±0.08 ^d	24.30±0.28 ^b	93.15±0.39 ^d	34.62±0.30 ^e	4.92±0.02 ^f	83.15±0.07 ^f
WT	157.80±0.30 ^a	76.67±0.48 ^a	81.13±0.18 ^a	159.12±1.12 ^b	82.45±0.64 ^d	5.96±0.04 ^c	88.25±0.35 ^c

Mean values followed by different superscript letters along the column differ significantly at $p < 0.05$.

Table 2. Proximate composition and energy value of flours and biscuits

Samples	Moisture (%)	Protein (%)	Ash (%)	Fat (%)	Total CHO (%)	Energy (cal/100g)
Flours						
YM	5.40±0.01 ^f	10.07±0.30 ^j	1.15±0.02 ^f	6.87±0.05 ^g	76.52±0.24 ^b	408.16±0.24 ^g
YMCP-1	4.81±0.01 ^g	14.09±0.19 ^g	1.88±0.01 ^g	5.03±0.03 ^h	74.20±0.15 ^c	398.39±0.13 ^h
YMCP-2	4.36±0.02 ^h	17.64±0.02 ^e	2.50±0.02 ^e	3.65±0.13 ⁱ	71.86±0.14 ^d	390.88±0.49 ⁱ
YMCP-3	4.14±0.01 ^h	22.01±0.56 ^c	2.94±0.01 ^c	2.44±0.01 ⁱ	68.48±0.57 ^e	383.93±0.06 ⁱ
CP	5.81±0.05 ^e	26.88±0.39 ^a	3.27±0.03 ^g	1.18±0.03 ^k	62.87±0.28 ^f	369.59±0.17 ^j
WT	5.17±0.02 ^g	12.12±0.35 ^h	0.64±0.02 ^k	0.28±0.01 ^l	81.80±0.33 ^a	378.21±0.24 ^k
Biscuits						
YM-B	8.49±0.45 ^b	8.92±0.24 ^k	1.31±0.03 ^h	19.02±0.45 ^a	62.27±0.27 ^g	455.91±3.90 ^a
YMCP-1B	7.73±0.28 ^c	12.02±0.13 ^h	2.14±0.06 ^f	16.58±0.33 ^b	61.54±0.78 ^g	443.44±0.30 ^b
YMCP-2B	7.11±0.08 ^d	15.19±0.17 ^f	2.72±0.05 ^d	15.20±0.37 ^c	59.79±0.66 ^h	436.69±1.39 ^c
YMCP-3B	6.86±0.19 ^d	18.87±0.22 ^d	3.21±0.06 ^b	14.05±0.29 ^d	57.03±0.20 ⁱ	430.00±0.93 ^d
CP-B	9.02±0.08 ^a	23.15±0.37 ^b	3.73±0.11 ^a	13.07±0.16 ^e	51.03±0.49 ⁱ	414.33±0.91 ^f
WT-B	7.85±0.11 ^c	10.96±0.11 ⁱ	0.77±0.03 ^j	12.15±0.41 ^f	68.27±0.45 ^e	426.29±1.51 ^e

Mean values followed by different superscript letters along the column differ significantly at $p < 0.05$.

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Table 3. Starch, amylose and amylopectin levels of flours and biscuits

Sample	Starch (%)	Amylose (%)	Amylopectin (%)	Amylose/Amylopectin
Flours				
YM	70.58±0.24 ^b	19.79±0.11 ^b	80.21±0.11 ⁱ	0.25±0.00 ^b
YMCP-1	68.66±0.39 ^c	18.19±0.18 ^c	81.82±0.18 ^h	0.22±0.00 ^c
YMCP-2	60.43±0.47 ^d	17.21±0.17 ^d	82.80±0.19 ^g	0.21±0.00 ^d
YMCP-3	54.64±0.10 ^f	15.93±0.12 ^e	84.07±0.12 ^f	0.19±0.00 ^e
CP	51.87±0.53 ^g	13.22±0.13 ^g	86.78±0.11 ^d	0.15±0.00 ^e
WT	80.68±0.26 ^a	21.81±0.29 ^a	78.20±0.30 ⁱ	0.28±0.00 ^a
Biscuits				
YM-B	61.05±0.29 ^d	15.91±0.01 ^e	84.09±0.01 ^f	0.19±0.00 ^e
YMCP-1B	57.23±0.49 ^e	14.04±0.07 ^f	85.96±0.07 ^e	0.16±0.00 ^f
YMCP-2B	50.20±0.43 ^h	12.05±0.35 ^h	87.95±0.35 ^c	0.14±0.01 ^h
YMCP-3B	46.20±0.44 ⁱ	10.15±0.23 ⁱ	89.86±0.23 ^b	0.11±0.00 ⁱ
CP-B	41.02±0.24 ⁱ	7.82±0.24 ⁱ	92.19±0.24 ^a	0.09±0.01 ⁱ
WT-B	68.01±0.66 ^c	18.27±0.18 ^c	81.73±0.18 ^h	0.23±0.01 ^c

Mean values followed by different superscript letters along the column differ significantly at $p < 0.05$.

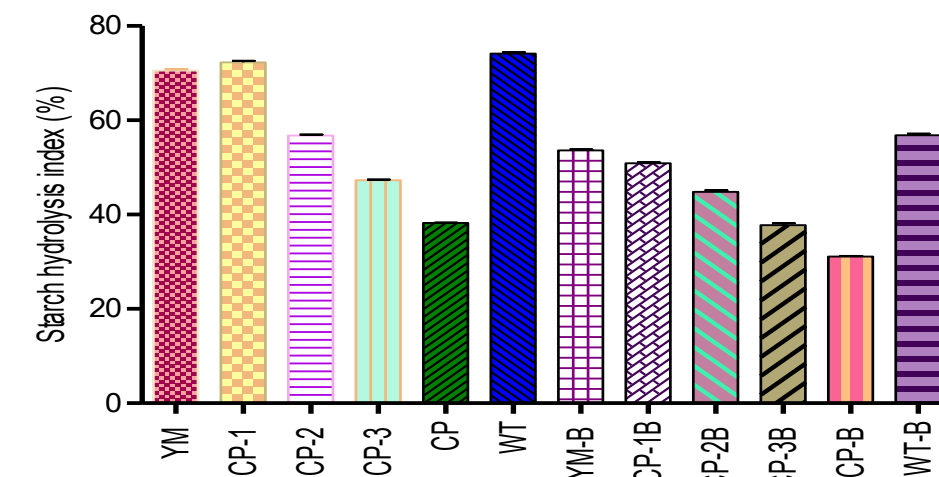


Figure 2. Starch hydrolysis index of flour and biscuits samples

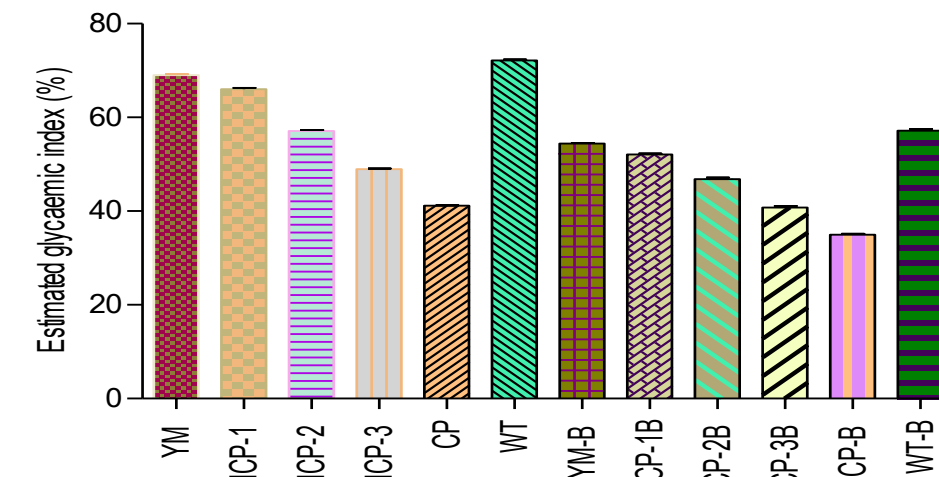


Figure 3. Estimated glycaemic index of flour and biscuits samples

Table 4. Sensory attributes of biscuits

Biscuits	Appearance	Taste	Colour	Crispiness	Flavour	Overall Acceptability
YM-B	4.46± 0.02 ^c	2.89±0.92 ^e	4.86±0.28 ^c	3.71±0.00 ^e	2.86±0.01 ^e	3.71±0.02 ^d
YMCP-1B	5.13±0.70 ^{bc}	3.31±0.92 ^{de}	3.89±0.28 ^d	3.69±0.10 ^b	3.60±0.62 ^{de}	4.46±0.01 ^{cd}
YMCP-2B	5.49±0.98 ^b	4.00±0.00 ^{cd}	5.23±0.97 ^{bc}	4.91±0.10 ^b	3.97±0.18 ^{cd}	4.49±0.52 ^{cd}
YMCP-3B	5.89±0.62 ^b	4.71±0.01 ^c	5.80±0.31 ^{bc}	4.82±0.15 ^b	4.69±0.02 ^c	4.91±0.90 ^c
CP-B	6.86±0.01 ^a	5.60±0.01 ^b	6.17±0.05 ^b	5.51±0.00 ^b	5.77±0.00 ^b	6.43±0.00 ^b
WT-B	7.51±0.00 ^a	7.49±0.00 ^a	7.20±0.00 ^a	6.42±0.00 ^a	7.31±0.00 ^a	8.00±0.00 ^a

Mean values followed by different superscript letters along the column differ significantly at $p < 0.05$.

CONCLUSIONS AND FURTHER RESEARCH NEED

Among the composite flours, YMCP-2 and YMCP-3 had the highest final an peak viscosities, respectively. Total carbohydrate, crude fat and energy value increased with increasing proportion of YM in both the composite flours and biscuits, while crude protein and ash contents increased as the proportion of CP increased. The levels of starch, amylose, amylose/amylopectin ratio, starch hydrolysis index and estimated glycaemic index of the composite flours and biscuits decreased with increasing proportion of CP. The overall acceptability of the composite biscuits improved with increasing proportion of CP. Hence, increasing the proportion of CP in YM-CP composite flour and biscuit may enhance their physicochemical properties, potential health benefits and sensory attributes. These findings may provide basis for diversifying the utilization of biofortified yellow maize and cowpea for improved human nutrition. Further research is needed to establish the nutraceutical potential of the biscuits in animal model and clinical trial.

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