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Indigenous pigmented corn (*Zea mays* L.) flour as substitute for all-purpose flour to improve the sensory characteristics and nutrient content of crackers

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ABSTRACT

Introduction: There is growing interest in using indigenous crops as alternative food sources that can address food and nutrition insecurity in developing countries. This study aimed to evaluate the nutrient content and sensory characteristics of crackers developed from indigenous pigmented corn (*Zea mays* L.) called *camotes*. **Methods:** Eleven *camotes* and all-purpose flour (APF) combinations were made into crackers following the modified method of Manley (2001) at University of the Philippines Los Baños. Sensory evaluation was conducted using the linear scale of quality scoring based on standard methods. Proximate composition analysis, nutrient contents and phytochemical components were conducted using standard methods. Data from the sensory evaluation were analysed using non-parametric Analysis of Variance (ANOVA), while results from the chemical analysis were analysed using One-Way ANOVA and Tukey's honestly significant difference (HSD) test. **Results:** Sensory characteristics of the cracker containing 80% *camotes* flour were comparable with those of the 100% APF cracker except in colour. Crackers containing 100% and 80% *camotes* flour had significantly higher levels of protein, dietary fibre, lysine, tryptophan, zinc, antioxidant activity, phenols, and flavonoids than crackers made of 100% APF. **Conclusion:** Crackers formulated at 80:20 *camotes*:APF blend compares most favourably with that from APF crackers. Incorporation of *camotes* flour into making of crackers increases its nutrient content. Such crackers can serve as a nutrient-dense alternative food source to address the food and nutrition insecurity situation in the Philippines.

Keywords: Cracker, pigmented corn, all-purpose flour

INTRODUCTION

Snack foods play an important part in people's lives especially for individuals who need to increase their energy intake, maintain normal blood glucose levels, prevent emotional eating and control weight. However, many of the snack foods available nowadays are high in calories, fat, salt, or sugar (or all of these), as well as contain processed ingredients and additives. One of the most popular cereal-based snacks are crackers. Crackers represent one of the most important segments of the baking

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industry because consumers view these products as having lower energy density compared to sugar biscuits (Serna-Saldivar, 2012).

Crackers are formulated with higher-protein flours, often from a mixture of hard and soft wheats. While wheat-based bakery products are generally considered as ideal, however in countries where climatic conditions do not allow wheat cultivation, or imported wheat is unaffordable, production of bakery products from 100% wheat flour is prohibitive. Hence, the use of composite flours in making bakery products has been widely researched (McWatters *et al.*, 2003).

A popular crop in the Philippines is corn (*Zea mays* L.) or maize. It is well known as "poor man's nutricereal" due to the presence of high contents of carbohydrates, fats, proteins, and important vitamins and minerals at a cheaper cost than other cereals. The value-added products prepared from specialty corns include traditional foods, infant foods, health foods, snacks, as well as savoury and baked products. Corn has a wide range of kernel colours such as white, yellow, orange, red, purple and black. In addition to its attractive colours, pigmented corn is rich in phytochemicals and many secondary metabolites, such as phenolic compounds, carotenoids, and flavonoids (Zilic *et al.*, 2012). If corn flour from pigmented corn is to be used as a substitute for all-purpose flour (APF) in cracker production, a more nutritious cracker could be produced. It is with this aim that a study was undertaken to produce crackers of acceptable sensory, nutritional, and microbial quality by utilising locally grown and available corn.

The general objective of the study was to evaluate the nutrient content and sensory characteristics of crackers developed from indigenous pigmented corn (*Zea mays* L.) or *camotes* flour. Specifically, the study aimed to evaluate the sensory characteristics in terms of colour, taste, texture/mouthfeel and general acceptability of developed *camotes* crackers; determine the nutrient content, such as the proximate composition (moisture, fat, protein, total ash, and carbohydrates), total dietary fibre, mineral content (iron and zinc), as well as lysine and tryptophan contents of *camotes* flour, all-purpose flour (APF), APF crackers. The study also determined antioxidant activity and phytochemical components (phenols, tannins, flavonoids, saponins, and alkaloids) of *camotes* flour, APF, APF crackers, and the most acceptable cracker developed.

MATERIALS AND METHODS

The study was conducted from May 2015 to August 2015 at the Bio-assay Laboratory of the Institute of Human Nutrition and Food (IHNF) at the University of the Philippines Los Baños (UPLB), Laguna. The *camotes* flour was procured from the Institute of Plant Breeding (IPB) Los Baños, Laguna while APF was purchased from a conveniently chosen supermarket. Various proportions of *camotes* and APF were made into crackers and evaluated for acceptability and sensory characteristics. Crackers from 11 formulations, consisting of the following *camotes:* APF ratio: 100:0, 90:10, 80:20, 70:30, 60:40, 50:50, 40:60, 30:70, 20:80, 10:90, and 0:100 were prepared following the modified method of Manley (2001). Yeast was mixed with water (25^{o}C) to form a suspension, to which the other ingredients were added and kneaded to form a smooth dough. The dough was stored for 2 hours in a refrigerator followed by sheeting to 1 mm thickness using a rolling pin. The dough was then cut into squares measuring 3cm x 3cm and baked at 350^{o}F for 15 minutes.

Sensory evaluation was conducted to identify the cracker with the most acceptable *camotes*:APF ratio. A panel comprising of 30 graduate students from the International House in UPLB were recruited to serve as judges. Each judge was served with six randomly arranged cracker samples for the first batch and five randomly arranged cracker samples for the second batch. The crackers were individually placed in identical small covered containers and coded with a three-digit number. Testing was done in two batches on the same day. The samples were evaluated using the 15-cm linear scale of quality scoring for colour, taste (saltiness), texture/mouthfeel (crispiness, hardness, grainy texture, cohesiveness of mass, and adhesiveness of mass), aftertaste, and general acceptability of the crackers. The most acceptable *camotes* and APF combination of crackers were used for the succeeding nutrient content analyses.

Proximate composition analysis was carried out following the standard methods of the Association of Analytical Chemist (AOAC) (1990). Moisture content was determined by oven-drying and fat content was estimated by soxhlet extraction. Protein content was estimated by micro Kjeldahl method and ash content by combustion. Lysine and tryptophan contents were determined based on the colorimetric methods described by Tsai, Hansel & Nelson (1972) and Opienska-Blauth, Charezinski & Berbec (1963), respectively. Zinc concentration was determined using zincon solution (Valdman, Areco & Alfonso, 2007) while iron concentration was measured following AOAC procedure. Enzymatic-gravimetric method (AOAC, 1990) was followed to determine dietary fibre. The antioxidant activity and phytochemical components were determined following the standard method of AOAC (1990). The percentage of antioxidant activity was assessed by 2,2 diphenyl-1-picryl hydrazyl (DPPH) free radical assay. The total phenolic content was determined based on the Folin-Ciocalteu method and total flavonoid was determined using aluminium chloride colorimetric method. All analyses were carried out in triplicates.

Results of the sensory evaluation of the 11 formulations of *camotes* and APF composite crackers were statistically analysed using non-parametric Analysis of Variance (ANOVA). The results obtained from the chemical analyses were analysed using One-Way ANOVA. If statistical differences were significant, Tukey's honestly significant difference (HSD) test was used for further analysed at < 5% level of significance. The results were expressed as mean values ± standard deviation.

RESULTS

It was observed that when more *camotes* flour was substituted for APF, the colour of the cracker became darker. The mean scores ranged from 3.33 to 11.43, which are described as very light brown to very brown (Table 1). Browning could also be attributed to Maillard reaction which occurs between reducing sugars and principally free amino acids and peptides (usually from proteins) when heated e.g. baking (Manley, 2011).

Taste is a key component in sensory evaluation testing. In the study, the intensity of saltiness was evaluated. The scores ranged from 3.65 to 4.12, which are described as bland. No significant difference in saltiness was found among the crackers.

Crispiness, the noise and force with which the sample breaks or fractures, was perceived in all formulations. It is considered as a desirable quality of crackers as it will determine consumer acceptability and represent a critical factor in limiting cracker shelf-life. Crispiness increased with increasing amounts of APF but were only significantly different between the 100% *camotes* cracker and 50 – 0% *camotes*:APF cracker.

Hardness, or the force required to bite through, is another textural attribute evaluated in the study. Too much hardness in a cracker is not desirable as it can cause difficulty in

Table 1. Mean sensory and acceptability scores of 11 cracker formulations

Camotes: APF Cracker	*Colour*	*Taste*	*Crispiness*	*Hardness*	*Grainy texture*	*Cohesiveness*	*Adhesiveness*	*Aftertaste*	*General acceptability*
(100:0)	11.43±2.50^{a}	4.02±1.63^{a}	7.93±2.96^{b}	11.07±1.50^{a}	9.70±3.77^{a}	9.65±4.23^{a}	5.23±3.25^{a}	7.23±3.70^{a}	9.07±1.0^{b}
(90:10)	11.40±2.36^{a}	3.87±2.26^{a}	8.50±2.70^{ab}	10.90±1.65^{a}	9.10±3.27^{ab}	9.53±3.98^{a}	5.73±3.16^{a}	6.83±4.59^{ab}	9.27±0.9^{ab}
(80:20)	9.87±2.49^{ab}	3.98±1.85^{a}	8.75±3.92^{ab}	9.55±3.11^{ab}	9.17±3.73^{ab}	9.00±3.04^{a}	6.03±3.01^{a}	6.95±3.96^{ab}	9.77±0.7^{a}
(70:30)	8.1±2.99^{bcd}	3.93±2.69^{a}	9.47±3.48^{ab}	9.52±2.47^{ab}	8.58±4.55^{ab}	8.47±2.98^{a}	6.70±3.16^{a}	6.00±3.90^{ab}	9.47±0.9^{ab}
(60:40)	8.47±3.22^{bc}	4.12±2.89^{a}	9.77±3.24^{ab}	9.37±3.19^{ab}	8.32±2.54^{ab}	8.37±2.90^{a}	6.80±4.00^{a}	5.63±3.14^{ab}	9.42±1.0^{ab}
(50:50)	7.57±3.19^{c}	4.07±1.66^{a}	9.73±2.87^{ab}	9.23±3.48^{ab}	8.55±3.33^{ab}	8.37±3.17^{a}	6.80±3.28^{a}	5.65±2.98^{ab}	9.40±1.0^{ab}
(40:60)	6.97±2.65^{cd}	3.83±2.28^{a}	10.37±2.89^{a}	8.57±2.99^{b}	8.00±3.33^{ab}	8.33±3.90^{a}	7.05±4.11^{a}	5.27±3.69^{ab}	9.37±1.2^{ab}
(30:70)	6.07±2.46^{d}	4.03±1.51^{a}	10.50±3.78^{a}	8.80±2.75^{b}	7.60±3.05^{ab}	8.30±2.56^{a}	7.47±3.01^{a}	5.10±3.14^{b}	9.33±0.8^{ab}
(20:80)	4.13±2.21^{e}	3.92±2.31^{a}	10.77±2.66^{a}	8.57±3.31^{b}	6.62±3.84^{b}	8.32±3.03^{a}	7.97±3.03^{a}	4.97±3.30^{ab}	9.30±0.5^{ab}
(10:90)	3.33±1.54^{e}	3.77±1.97^{a}	10.80±2.51^{a}	8.43±3.76^{b}	6.65±3.74^{b}	8.13±3.56^{a}	7.90±3.79^{a}	4.28±2.87^{b}	9.20±0.4^{ab}
(0:100)	3.33±2.48^{e}	3.65±2.25^{a}	10.77±3.07^{a}	8.07±2.99^{b}	6.63±2.66^{b}	7.87±3.21^{a}	8.00±3.83^{a}	4.23±3.26^{b}	9.18±1.0^{ab}

*Data is expressed as means with different superscripts in columns indicating statistically significant difference at $p \leq 0.05$, (n=30), using Tukey's HSD test.

Legend:

	Colour	**Taste (Saltiness)**	**Crispiness**	**Hardness**	**Grainy texture**	**Cohesiveness**	**Adhesiveness**	**Aftertaste**	**General acceptability**
15	Dark brown	Very salty	Very crispy	Very hard	Very grainy	Very cohesive	Very sticky	Highly perceptible	Extremely acceptable
0	Very light brown	Bland	Not crispy	Soft	None	Loose	Not sticky	Imperceptible	Not acceptable

chewing the product. The study showed that substituting up to 80% *camotes* flour to APF can produce a cracker with similar hardness as that of the APF cracker. Crackers with more than 80% *camotes* flour yielded a harder texture than the APF cracker. Geometrical attribute (grainy texture) is described as the amount of loose and grainy particles resulting from bite. The cracker with the least rating in the study was the APF cracker (100% APF). The rest of the formulations had higher mean scores than the APF cracker especially those that had more than 20% of *camotes* flour. Although there were notable differences in the mean scores, significant difference was only noted between APF cracker and the cracker with 100% *camotes* flour.

Cohesiveness of the crackers or the degree to which mass holds together was observed in all the formulations but were not statistically different. Adhesiveness refers to the degree to which mass sticks to the roof of the mouth or teeth (Lawless & Heymann, 2010). In this test, judges were instructed to place the sample on their tongue and press it on the palate, and rate the force required to remove it from the palate using the tongue. Results showed no significant differences among all formulations. The corn flavour or aftertaste in the crackers was slightly perceived in all the formulations except in 100% *camotes* flour, which was significantly different from that of the APF cracker. Although no previous study has replaced APF with *camotes* flour in the production of crackers, the results are consistent with other studies where findings showed that aftertaste is positively affected when crop substitution in bakery products is increased (Noor Aziah & Komathi, 2009). The 100% *camotes* cracker had the lowest mean score for general acceptability and was the only cracker that was significantly different from the APF cracker, while the cracker made with 80% *camotes* flour had the highest mean score and was the most acceptable. Among all the sensory attributes, significant difference between 80:20 *camotes*:APF cracker and the APF cracker was noted only in colour.

Proximate composition of *camotes* flour and APF

Significant differences between the *camotes* flour and APF were observed in moisture, ash, fibre, protein, and fat while no significant difference was noted in carbohydrates (Table 2).

Moisture content was almost 50% significantly lower in *camotes* flour at 3.69% than in APF at 6.58%. The low moisture contents of the two flours were within the recommended limit of <10.00% for longer storage periods.

The study also revealed that *camotes* flour was 13.0% significantly higher in ash, 38.4% higher in fibre, 30.0% higher in protein, but 57.0% lower in fat than the APF. These results suggest that if *camotes* flour is used as a substitute for

Table 2. Mean proximate composition of *camotes* flour and APF

Components[†]	*Camotes flour*	*APF*
Moisture (%)	3.69 ± 0.12^b	6.58 ± 0.24^a
Ash (g/100g)	1.69 ± 0.05^a	1.47 ± 0.01^b
Fibre (g/100g)	2.32 ± 0.15^a	1.43 ± 0.07^b
Protein (g/100g)	9.71 ± 0.82^a	6.85 ± 0.41^b
Fat (g/100g)	1.23 ± 0.09^b	2.84 ± 0.20^a
Carbohydrate (g/100g)	81.35 ± 0.81^a	80.82 ± 0.67^a

[†]Values are expressed as g/100g dry basis except for moisture content.
[a,b] Means in same row with different superscripts differ significantly ($p<0.05$) using Tukey's HSD test.

APF, the resulting cracker could have higher fibre and protein content.

Nutrient content analysis of *camotes* flour and APF

All foods of vegetable origin contain fiber, but in variable quantities (Sardesai, 2011). The study revealed that total dietary fiber in *camotes* flour was 19.4% significantly higher than in APF (Table 3).

The iron and zinc analyses revealed that *camotes* flour was 34.1% significantly lower in iron content but more than 25.0% significantly higher in zinc content than APF. *Camotes* flour also had almost three times higher lysine content when compared to APF. Tryptophan was found to be 35.0% significantly higher in *camotes* flour than in APF. This implies that substituting *camotes* flour for APF would yield a cracker that has higher lysine and tryptophan contents.

The red pigment of the *camotes* corn could be attributed to anthocyanidins which, according to research, are a unique subgroup of flavonoids responsible for the distinctive colours in plants (De La Rosa, Alvarez-Parilla & Gonzales-Aguilar, 2009). Pigmented corn is a rich source of phytochemicals which are regarded as an important source of antioxidants in cereals (Khampas *et al.,* 2013). Phytochemicals are bioactive non-nutrient plant compounds that have been associated with reduced risk of major chronic diseases. Phenolics are compounds with one or more aromatic rings and one or more hydroxyl groups such as phenolic acids, plant lignans, alkylresorcinols, and flavonoids. In principle, the higher the amount of phenolics and other antioxidant compounds, the greater the potential to affect antioxidant capacity and this has been well documented *in vitro* using a variety of assays (Allen & Prentice, 2012). Phytochemicals such as phenols and flavonoids were significantly higher in *camotes* flour than in APF, which could have contributed to the significantly higher antioxidant activity observed in *camotes* flour.

Proximate composition of 80:20 *camotes*:APF cracker and APF cracker

The trend in the differences observed in the proximate composition of *camotes* flour and APF was also observed when the flours were processed into crackers. Despite the addition of other ingredients, the 80:20 *camotes*:APF cracker remained significantly lower in moisture content by 35.0% and fat by 15.0%, and significantly higher in ash, fibre, protein, and carbohydrates by 4.0%, 33.0%, 23.6%, and 2.6%, respectively, than the APF cracker (Table 4).

Table 3. Nutrient content and phytochemical components analyses of *camotes* flour and APF

Components†	*Camotes flour*	*APF*
Total Dietary Fibre (%)	2.73±0.01^{a}	2.20±0.0^{b}
Iron (mg/100g)	2.7±0.10^{b}	4.10±0.10^{a}
Zinc (mg/100g)	2.10±0.00^{a}	1.50±0.00^{b}
Lysine (mg/100g)	427.66±2.27^{a}	158.08±2.27^{b}
Tryptophan (mg/100g)	50.51±0.72^{a}	32.85±0.10^{b}
Antioxidant Activity (%)	51.92±0.41^{a}	18.3±0.78^{b}
Phenols (mg/100g expressed as g/catechin eq/g)	10.00±0.03^{a}	2.50±0.20^{b}
Flavonoids (mg/100g expressed as mg gallic acid eq/g)	3.73±0.28^{a}	1.05±0.18^{b}

†Values are expressed as mg/100g dry basis

a,b Means in same row with different superscripts differ significantly ($p<0.05$) using Tukey's HSD test.

Table 4. Mean proximate composition of 80:20 *camotes:APF* cracker and APF cracker

Components†	*80:20 camotes:APF cracker*	*APF cracker*
Moisture (%)	4.69±0.20[b]	7.23±0.21[a]
Ash (g/100g)	1.44±0.05[a]	1.38±0.00[a]
Fibre (g/100g)	1.58±0.09[a]	1.06±0.01[b]
Protein (g/100g)	7.95±0.06[a]	6.07±0.02[b]
Fat (g/100g)	10.37±0.15[b]	12.23±0.13[a]
Carbohydrate (g/100g)	73.97±0.21[a]	72.02±0.10[b]

†Values are expressed as g/100g dry basis except for moisture content.
[a,b] Means in same row with different superscripts differ significantly ($p<0.05$) using Tukey's HSD test.

Nutrient content and phytochemical components analyses of 80:20 *camotes*:APF cracker and APF cracker

It was observed that the 80:20 *camotes*:APF cracker was 17.1% significantly higher in dietary fibre than the 100% APF cracker (Table 5). According to Brennan & Grandison (2012), the amount of dietary fibre could have an effect in the textural characteristics of food, in that addition of dietary fibre increases the hardness of the products as a result of its effect on cell wall thickness. This is consistent with the sensory evaluation findings in the study where the hardness score of the cracker increased when substitution of *camotes* flour to APF was increased.

The 80:20 *camotes*:APF cracker had 11.6% significantly less iron but 26.0% significantly more zinc than the APF cracker. This was expected since *camotes* flour, which had lower iron but higher zinc contents than APF, was used in higher proportion.

The 80:20 *camotes:*APF cracker had 50.0% significantly more lysine content and 25.0% significantly more tryptophan content than the APF cracker. This proved that supplementation of *camotes* flour to APF could produce a cracker that has a better protein quality because of the increased levels of lysine and tryptophan.

The trend in the phytochemical components and antioxidant activity observed in flours was also observed in the crackers. Phenols and flavonoids were still significantly higher in 80:20 *camotes*:APF cracker than in APF cracker at 75.0% and 65.0%, respectively,

Table 5. Nutrient content and phytochemical components analyses of 80:20 *camotes:*APF cracker and APF cracker

Components†	*80:20 camotes: APF cracker*	*APF cracker*
Total Dietary Fibre (%)	2.11±0.12[a]	1.75±0.12[b]
Iron (mg/100g)	2.91±0.00[b]	3.29±0.10[a]
Zinc (mg/100g)	1.90±0.00[a]	1.40±0.00[b]
Lysine (mg/100g)	400.40±2.27[a]	146.68±3.10[b]
Tryptophan (mg/100g)	45.50±0.57[a]	33.31±0.55[b]
Antioxidant Activity (%)	40.10±0.96[a]	12.90±0.41[b]
Phenols (mg/100g expressed as g/catechin eq/g)	5.30±0.01[a]	1.41±0.02[b]
Flavonoids (mg/100g expressed as mg gallic acid eq/g)	2.38±0.21[a]	0.85±0.13[b]

†Values are expressed as mg/100g dry basis.
[a,b] Means in same row with different superscripts differ significantly ($p<0.05$) using Tukey's HSD test.

despite having other added ingredients. These components have contributed to the antioxidant activity which was 67.8% higher in 80:20 *camotes*:APF cracker than in APF cracker. This showed that using *camotes* flour as a substitute for APF could produce crackers with improved levels of phytochemical components and antioxidant activity.

DISCUSSION

The study revealed that more protein and less fat were obtained from the cracker with 80% *camotes* flour and 20% APF than from the 100% APF, although the 80:20 *camotes*:APF cracker and APF cracker yielded almost the same amount of energy per 100g. The 80:20 *camotes:*APF cracker had better protein quality than the APF cracker, as the former provides almost 50% of both lysine and tryptophan requirements for children. On the other hand, APF cracker provides <20% of lysine and <30% tryptophan requirements for children.

Iron deficiency is considered the most common single-nutrient deficiency disease in the world, particularly affecting women, children, and female adolescents. Meanwhile, zinc deficiency is a serious nutritional problem that negatively affects growth and intellectual and sexual development (Preedy & Watson, 2014). The study showed that 80:20 *camotes*:APF cracker can be a source of iron in children up to 5 years and a source of zinc in children up to 12 years. Inclusion of the 80:20 *camotes:*APF cracker in the daily diet could contribute to the iron and zinc requirements and help prevent inadequacy.

The study also revealed that consuming one serving (20 g) of the 80:20 *camotes*:APF cracker provides 11-14% of the daily requirement for dietary fibre in adults, compared to 9-11% from 20 g of APF cracker. Adequate intake of dietary fibre each day helps to maintain bowel integrity by increasing stool weight and promoting normal laxation (Wilson *et al.*, 2010). It may also protect against heart attack and stroke by lowering blood pressure, improving blood lipids, reducing inflammation, and reducing the risk of type 2 diabetes by slowing glucose absorption which helps to prevent glucose surge and rebound (Whitney *et al.*, 2011).

The study showed that 80:20 *camotes:*APF cracker has significantly higher phytochemical compounds and antioxidant activity than APF cracker. This is beneficial because dietary antioxidant substances contribute to health and well-being by delaying or preventing the negative impact of oxidation that plays a role in many diseases like diabetes, heart disease, cancer, and neurodegenerative disorders (Divya & Pandey, 2014). Phenolic compounds and flavonoids found in the 80:20 *camotes*:APF cracker have the potential to function as important radical-scavenging antioxidants. It has been said that flavonoids exert their antioxidant activity by inhibiting the activities of enzymes including xanthine oxidase, myeloperoxidase, lipoxygenase, and cyclooxygenase, by chelating metal ions, and by interacting with other antioxidants such as ascorbate (Divya & Pandey, 2014).

CONCLUSION

Crackers made from 80:20 *camotes*:APF blend was found to be most acceptable based on sensory evaluation, and nutrient and phytochemical contents. Hence, the *camotes* flour showed potential for use in producing nutrient-dense alternative foods to address food and nutrition insecurity concerns in developing countries.

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Authors' contributions

ZGS, principal investigator, conceptualised and designed the study, data analysis and interpretation, prepared the draft of the manuscript and reviewed the manuscript; CBJ advised on the data analysis and reviewed the manuscript; EID advised on the interpretation and reviewed the manuscript, WAH advised on the data analysis and interpretation and reviewed the manuscript.

Conflicts of interest

The authors declare that there is no conflict of interest.

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