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อิทธิพลของคีนวาห์และเวลาในการสับนวดที่มีต่อคุณภาพของนักเก็ตไก่ไขมันต่ำ

The Influence of Quinoa and Time of Chopping Process on Quality of Low-fat Chicken Nuggets

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บทคัดย่อ

งานวิจัยนี้ศึกษาถึงผลของคีนวาห์ที่มีต่อลักษณะทางกายภาพของนักเก็ตไก่ไขมันต่ำด้วยแป้งบุกในด้านต่างๆ ได้แก่ ปริมาณผลผลิต เสถียรภาพของอิมัลชัน ความชื้น พีเอช การหดตัว ความแน่นเนื้อ และสี โดยใช้คีนวาห์ที่ระดับปริมาณ 10 เปอร์เซ็นต์ ในนักเก็ตที่ใช้เวลาในการสับนวดด้วยวิธีมาตรฐาน (3 นาที) 5 และ 7 นาที เทียบกับนักเก็ตสูตรควบคุม (ไม่เติมคีนวาห์) ผลการทดลองแสดงให้เห็นว่า นักเก็ตเสริมคีนวาห์ที่ใช้เวลาสับนวดมาตรฐานมีค่าปริมาณผลผลิต เสถียรภาพของอิมัลชัน และความแน่นเนื้อเพิ่มขึ้น ส่วนการหดตัวและความสว่างมีค่าลดลง การเพิ่มเวลาในการสับนวดเป็น 5 นาที ส่งผลให้นักเก็ตมีปริมาณผลผลิตและเสถียรภาพของอิมัลชันเพิ่มขึ้น ส่วนลักษณะทางกายภาพในด้านอื่นๆ ไม่แตกต่างกันอย่างมีนัยสำคัญ อย่างไรก็ตามนักเก็ตมีปริมาณผลผลิตและเสถียรภาพของอิมัลชันลดลงเมื่อสับนวดนาน 7 นาที นอกจากนี้ นักเก็ตไก่เสริมคีนวาห์ 10 เปอร์เซ็นต์ ที่ใช้เวลาสับนวด 5 นาที มีปริมาณกรดไทโอบาร์บิทูริกลดลง หลังจากเก็บไว้ที่อุณหภูมิ 10 – 12 ºC

ABSTRACT

The research study focused on the effect of quinoa on the physical characteristics of the low-fat nuggets' quality, including cooking yield, emulsion stability, moisture, pH, shrinkage, firmness, and color. The quinoa was added to the nugget at 10% quinoa, and the tested nuggets were processed with varied chopping time including 3 (standard process), 5 and 7 minutes. In comparison to the control nugget (3 minutes), the nugget with quinoa exhibited a rise in cooking yield, emulsion stability, and firmness, as well as a decrease in shrinkage and lightness. Increasing the chopping time to 5 minutes significantly increased the cooking yield and emulsion stability; however, a lengthy (7 minutes) chopping process could decrease these two parameters. At the same time, other physical characteristics were comparable.

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The 10% quinoa nugget with 5 minutes of chopping is the best formulation, providing less thiobarbituric acid after four weeks of storage (10 – 12 ºC).

คำสำคัญ: ผลิตภัณฑ์เนื้อสัตว์ คีนวาห์ แป้งบุก เวลาในการสับนวด คุณภาพทางกายภาพ
Keywords: Meat Product, Quinoa, Konjac Flour, Chopping Process, Physical Quality

INTRODUCTION

Healthier meat products with lower fat and higher fiber are still desired for consumers' lifestyles to lower the risk of health problems, including hypertension, heart disease, obesity, diabetes, constipation, and colon cancer (Pathera *et al*., 2017). The global meat market is anticipated to reach USD 1.6 trillion by 2028, expanding at a 2.3% CAGR during the forecast period (2023 - 2028) (The International Market Analysis Research and Consulting Group (Imarc group, 2022). Most researchers have primarily used hydrocolloids to make low-fat meat products. These additives can bind with water to give a thickening or viscosity effect and create stable gels that mimic the texture, viscosity, creaminess, and mouthfeel of fats (Peng and Yao, 2017). Konjac flour (*Amorphophallus konjac*), a high water-binding glucomannan, is popularly used as a fat replacement in some foods because of its thickening, gelling, and stabilizing effects. It creates a slippery, fat-like gel that replaces low-fat meat and other products (Akesowan, 2016). Kim *et al*. (2019) showed the replacement of 50% pork fat by konjac gels in the low-fat frankfurter improved the overall quality of the water-holding capacity, cooking loss, and consumer acceptance. However, several studies also mentioned that meat products with konjac gel cause higher cooking loss, lower water-holding capacity (WHC), and lower emulsion stability (Verma *et al*., 2019; Fernández-López *et al*., 2020a; Alkobeisi *et al*., 2022).

Natural dietary fibers have been applied in meat products to retain moisture, provide texture and mouthfeel, and increase water-holding texture and viscosity. With these functional properties, they will be a good alternative to combine with konjac gel for improving WHC and reducing expressible water. Quinoa (*Chenopodium quinoa*), a superfood that has a high dietary fiber and protein content, has a higher lysine (5.1 – 6.4%) and methionine (0.4 – 1.0%) content than common cereals and legumes (Park *et al*., 2021). It is rich in vitamins B2 and B6, potassium, calcium, manganese, linoleic acids, and antioxidants like coumaric acids, quercetin, and kaempferol (Fernández-López *et al*., 2020b). Quinoa can absorb water well and displays diversified functions in various food applications, such as fat- and water-binding capacity, non-caloric bulking effect, gel-forming ability, emulsification, and foaming properties (Alkobeisi *et al*., 2022). Many studies reported the successful impact of quinoa on improving meat product quality, such as goat meat nuggets added with amaranth and quinoa seed flour (Verma *et al*., 2019) and bologna-type sausages with increasing technological properties incorporated with black quinoa (Fernández-López *et al*., 2020b).

The quality of meat products is related to many factors, such as the quality of the meat, ingredients, and processing conditions. In the process of chopping, the raw materials are mixed to achieve homogenous consistency and to bind all the ingredients added (Devatkal *et al*., 2014). This procedure is also crucial for the extraction of myofibrillar proteins, which are responsible for the development of emulsified meat products, contributing to better functional properties such as gel formation and water-holding capacity, and

reducing the separation of water and fat components (Krzywdzinska-Bartkowiak *et al*., 2022). For the best quality of functional meat products, the optimal chopping time should be finished. Therefore, this study aimed to find out the impact of quinoa on the low-fat chicken nuggets with konjac flour at various chopping times.

MATERIALS AND METHODS

Materials

Konjac flour (Chengdu Newstar Chengming Bio-Tech Co., Ltd, China), xanthan gum (Keltrol®, CP Kelco, San Diego, CA, USA), sodium phosphate (Carlo Erba Reagenti, Rodano, Italy) and quinoa seed (Arrowhead Mills®, The Hain Celestial Group, Inc., CO, USA) were used. Other ingredients were whole egg, evaporated milk, sugar, salt, rice flour, black pepper, and white onion.

Preparation of konjac gel

A gel was prepared by adding a 1.5 g konjac-xanthan (3:1) blend into 100 ml distilled water, mixed, and heated at 80 – 85 ºC until reducing to one-third volume. After cooling down, the konjac gel was ground through a 0.4 cm disk and refrigerated at 10 – 12 ºC for before processing.

Preparation of cooked quinoa

Quinoa seed was cleaned, added into a saucepan, and poured over with water (quinoa:water; 1:2). Heated until boiling and continuously simmered for 15 – 20 minutes. The cooked quinoa was kept in a refrigerator (10 ± 2 ºC) before use.

Preparation of low-fat nuggets

The low-fat control nugget (a non-bread recipe) included 56.6% chicken meat, 4.2% chicken skin, 27% konjac gel, 6.2% whole eggs, 2.2% evaporated milk, 1.3% sugar, 1% salt, 0.7% rice flour, 0.4% black pepper, and 0.4% chopped white onion. Thawed minced chicken meat and fat were thoroughly mixed with konjac gel for 30 seconds using a food processor (Model MK-F300, Panasonic, Malaysia). Other ingredients, such as cooked quinoa, whole egg, evaporated milk, sugar, salt, wheat flour, black pepper, and white onion, were added and chopped for 3 minutes. Each raw nugget (4 × 2 × 1 cm^3) was manually shaped, stored frozen for 1 hour, and then fried with palm oil (180 ± 2 ºC) for 3 minutes. each side (core temperature 80 ± 2 ºC). The tested nuggets were prepared by substituting konjac gel for quinoa, while chopping treatments were set at 3, 5 and 7 minutes.

Physical analysis

Uncooked nuggets were weighed before cooking, and then cooked nuggets were re-weighed. The cooking yield was calculated based on the cooked weight relative to the uncooked weight. A cooked sample (5 g) in 50 ml distilled water was thoroughly mixed and measured using a pH meter (model 320, Mettler-Toledo Ltd, Essex, UK).

Emulsion stability was performed according to the method described by Verma *et al*. (2016). Briefly, an uncooked sample (10 g) was placed into a plastic tube and heated at 80 ºC for 30 minutes. The percentage of weight loss after heating was recorded.

The difference in diameter between uncooked and cooked nuggets was calculated as the percentage of nugget shrinkage.

A Lloyd texture analyzer (LRX Plus, Lloyd Instruments, Hampshire, UK), with speed of 250 mm/min was performed with a cutting test cell. The peak force (N) was recorded and expressed as the firmness value.

The nugget was diametrically cut and determined interior color. The color analysis composed of L* (0 = black, 100 = white), a* (+ = red, – = green), and b* (+ = yellow, – = blue) were measured. A colorimeter (Color Flex, Hunter Associates Laboratory, Reston, VA) was used.

Thiobarbituric acid value

According to Tarladgis *et al*. (1960), refrigerated nuggets (10 – 12 °C) at 0, 1, 2, 3 and 4 weeks were tested for TBA values (mg malonaldehyde per kg sample). The distillation procedure was used, and TBA was determined using a UV–Vis spectrophotometer (UV-1601, Shimadzu Corporation, Kyoto, Japan).

Statistical analysis

Analysis of variance (ANOVA) and Duncan's new multiple range test analyzed by the SPSS version 17.0 was performed for statistical differences. The preference mapping was calculated by principal component analysis (PCA) with the Program R (R Foundation for Statistical Computing, Vienna, Austria).

RESULTS AND DISCUSSION

Physical properties of low-fat nuggets with quinoa

Table 1 Physical properties of konjac nuggets with quinoa at different chopping times

Parameters	Chopping time (minutes)			
	Control	3 minutes	5 minutes	7 minutes
Cooking yield (%)	83.95 ± 1.18^{c}	85.45 ± 0.95^{b}	86.34 ± 1.02^{a}	85.08 ± 0.78^{b}
Emulsion stability (%)	91.16 ± 1.32^{c}	92.48 ± 1.58^{b}	93.04 ± 0.98^{a}	91.77 ± 1.30^{c}
Moisture (%)	67.86 ± 1.15^{c}	69.95 ± 0.80^{b}	68.36 ± 0.75^{bc}	69.05 ± 0.94^{b}
pH	6.12 ± 0.09^{b}	6.25 ± 0.16^{a}	6.25 ± 0.16^{a}	6.26 ± 0.16^{a}
Shrinkage (%)	16.39 ± 1.40^{a}	15.62 ± 1.26^{b}	14.82 ± 1.14^{bc}	15.95 ± 1.46^{b}
Firmness (N)	25.36 ± 1.08^{b}	26.94 ± 1.40^{a}	27.65 ± 1.75^{a}	26.07 ± 1.64^{a}
L*	69.54 ± 0.28^{a}	68.04 ± 0.42^{b}	67.35 ± 0.28^{b}	68.70 ± 0.56^{ab}
a*	2.28 ± 0.16^{a}	2.37 ± 0.29^{a}	2.20 ± 0.66^{a}	2.46 ± 0.50^{a}
b*	17.84 ± 0.85^{b}	18.52 ± 0.58^{a}	18.82 ± 0.85^{a}	18.45 ± 0.62^{a}

Means in the same row with different superscripts are significantly different ($p < 0.05$)

With the standard chopping procedure at 3 minutes, the incorporation of quinoa significantly showed higher cooking yield, emulsion stability, moisture, pH, and firmness than the control nugget, but less shrinkage ($p < 0.05$) (Table 1). It is because quinoa has a high-water affinity, which helps retain water molecules and slows down the coalescence of fat globules. This could subsequently increase the stability

of the meat emulsion, resulting in better characteristics (Alkobeisi *et al*., 2022). Cooking yield, a parameter relating to the juiciness of nuggets, increased in conjunction with moisture content as quinoa was added compared to the control. Based on this, konjac gel can absorb water well and display a more viscous batter, reducing water and fat separation and contributing to maintaining moisture during cooking (Lee and Chin, 2019). According to Sayas-Barberá *et al*. (2021), the high water-binding capacity of black quinoa influenced the better emulsion stability and rheological characteristics of meat patties during freezing storage.

The nuggets with quinoa significantly showed ($p < 0.05$) an increase in pH compared to the control. It might be due to the higher pH of quinoa (pH 7.0 – 7.4) than that of chicken meat (pH 5.6 – 6.2). Incorporating the quinoa also decreased ($p < 0.05$) the nugget's shrinkage, possibly because the quinoa could hold moisture and reduce water loss during frying. Firmness is expressed as the peak force required to shear a nugget. The 10% quinoa nugget presented a higher firmness than the control (Table 1), indicating that its texture is firmer and more cohesive. Incorporating quinoa might induce a protein-quinoa gel network, leading to a texture-modified attribute (Öztürk-Kerimoğlu *et al*., 2020).

When considering the interior color of nuggets, the addition of quinoa lowered L* but increased b* against the control ($p < 0.05$), while the a* value was comparable ($p > 0.05$). These findings showed that the nuggets got darker as the quinoa was incorporated, which might be due to the reduction in white chicken meat content with increasing brown quinoa content. Verma *et al.* (2019) reported that decreased lightness in meat products is correlated with a decrease in meat content. Many researchers agreed that the proportion of lean meat and non-meat ingredients, the amount of water and fat, and the types of non-meat components may all affect how colored functional meat products turn out (Akesowan, 2021; Kyriakopoulou *et al*., 2021).

Effect of chopping time on nugget quality

When extending the chopping time from 3 to 5 minutes, the cooking yield and emulsion stability were significantly increased ($p < 0.05$) in the nuggets, while moisture, pH, shrinkage, firmness, and L*, a*, and b* values were comparable ($p > 0.05$). Krzywdzinska-Bartkowiak *et al*. (2022) indicated that the chopping process is important for the extraction of myofibrillar proteins, which are responsible for the structure and functionalities of meat texture. Additionally, the charged amino acid lysine in quinoa may modify and reinforce the myofibrillar proteins. As explained by Devatkal *et al*. (2014), the optimal chopping time may help extract meat proteins to bind water molecules in the loosened protein network and form a well-emulsified batter.

Table 1 also denotes that the chopping procedure up to 7 minutes significantly lowered the cooking yield and emulsion stability of the nuggets compared to those with 5 minutes, while other parameters did not change. The result implies that chopping too long might increase batter temperature and negatively affect protein denaturation and emulsion stability, resulting in changes to the product quality. It is noted that the batter is less thickened, relating to decreasing binding properties in the batter and receiving less firmness. Meng *et al*. (2022) suggested that increasing chopping temperature was noticed with a reduction in moisture, reducing extracted salt-soluble myofibrillar proteins. This phenomenon impacted

the continuous phase to fully wrap the dispersed phase in meat batter, which affected the firmness of nuggets.

Principal component analysis

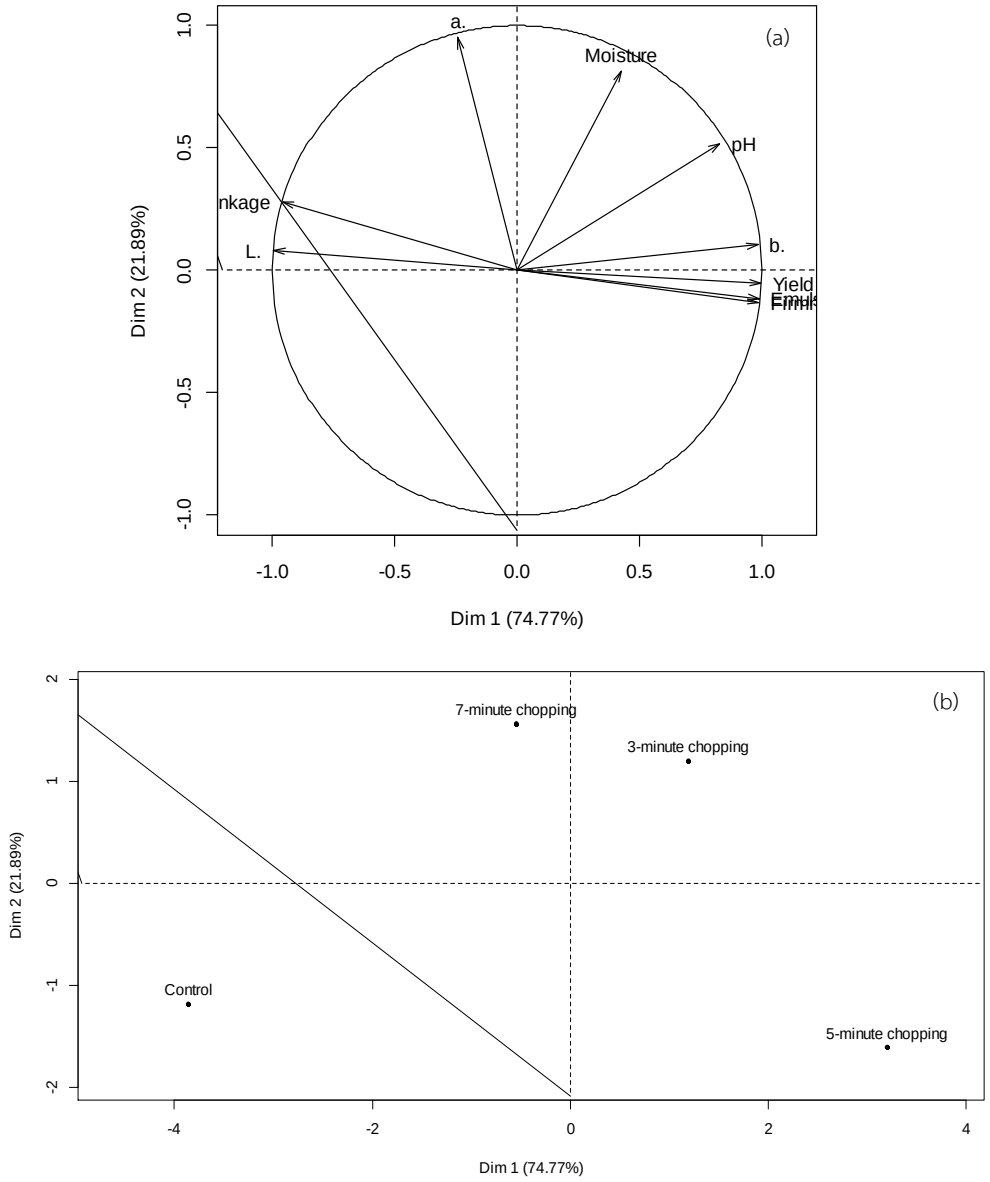

Figure 1 PCA graphs of low-fat nuggets with quinoa at different chopping times; projection of variables (a) and projection of samples (b)

The PCA results in Figure 1a show that PC 1 and PC 2 can explain 74.77% and 21.89%, respectively, showing the high cumulative value (97.66% in total) of the observed variation. The result showed that consumers can reliably and satisfactorily distinguish between different nuggets. The physical characteristics, including cooking yield, emulsion stability, moisture, pH, firmness, shrinkage, and color, could differentiate the samples. Instead of analyzing all variables, PCA analysis will focus on PC 1, where cooking yield and lightness (L*) had a positive correlation of 0.99 and a negative correlation of -0.99, respectively. PC 2 nonetheless demonstrated a positive correlation with redness (a*) (0.95) and a slight negative correlation

with firmness (-0.13). The 10% quinoa addition promoted the nugget with a higher cooking yield and a darker color tonality, which did not have a harder texture. According to Figure 1b, increasing the chopping time to 5 minutes produced the quinoa nuggets with better physical characteristics, which were in the lower right quadrant. Still, the nuggets with 3- and 7-minute chopping times were positioned in the same group.

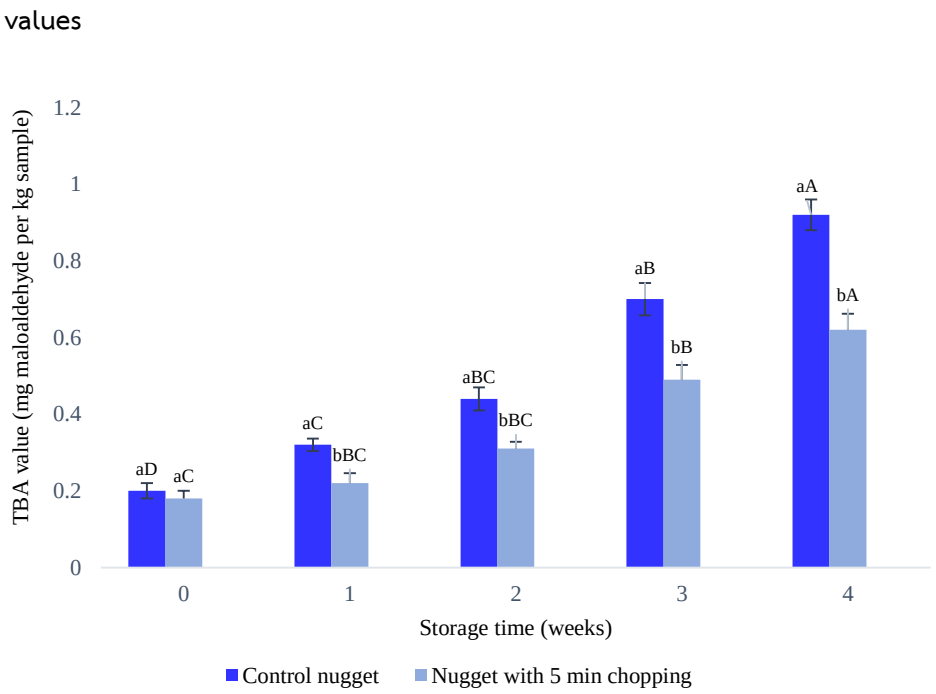

Figure 2 Oxidative rancidity of the control nugget (no quinoa) and konjac-quinoa nuggets with 5 minutes chopping. Different capital letters are significantly different regarding storage time ($p < 0.05$), while different lowercase letters are significantly different regarding formulation ($p < 0.05$)

There were no significant differences in TBA values between the control and 10% quinoa nuggets in the first week (Figure 2). The modified nuggets had lower TBA values from the second to fourth weeks of refrigerated storage than the control. This can be explained based on several factors, such as the different initial fat content between the control (6.64%) and 10% quinoa (2.89%) nuggets (data not shown). Additionally, the lower heme in the 10% quinoa formulation might reduce the lipid oxidation. The natural antioxidants in quinoa, such as ferulic acid and coumaric acid, may suppress peroxyl radicals, which cause lipid oxidation (Masoodi, 2016). According to Pawar *et al.* (2012), whole liquid eggs with egg yolk phospholipids can reduce the TBA levels in chicken nuggets. Kumar *et al.* (2013) revealed that green banana and soybean hull flour increase the amount of soluble dietary fiber in chicken nuggets, absorbing free fats and reducing lipid oxidation. A similar extended shelf life was found for frankfurters containing shiitake (dietary fiber) after refrigerated storage (Akesowan, 2016). In this study, after 4 weeks of storage, the TBA values found in the control and 10% quinoa samples were 0.85 and 0.62 mg malonaldehyde per kg sample, respectively (data not shown). Hence, quinoa, a soluble dietary fiber, can reduce lipid oxidation in foods.

CONCLUSIONS

The addition of 10% quinoa with a standard chopping (3 minutes) improved the physical characteristics of the low-fat nuggets, including cooking yield, emulsion stability, moisture, shrinkage, and firmness. Extending the chopping time to 5 minutes increased the cooking yield and moisture of the nuggets. Nevertheless, the lengthy (7 minutes) chopping process reduced the nugget's cooking yield and moisture. Quinoa made the nuggets darker. The 10% quinoa nugget also decreased the levels of oxidative rancidity after 4 weeks of storage. The quality comparison between the nuggets prepared with quinoa seed and quinoa flour and the storage stability are planned for the further investigation.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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