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PINEAPPLE JAM PHYSICOCHEMICAL AND SENSORY EVALUATION WITH ADDED PINEAPPLE PEEL

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ABSTRACT

The aim of this research was to evaluate the effect of pineapple peel (PP) addition on pineapple jam physicochemical and sensory characteristics. Five pineapple jam formulations were prepared: standard F1 (0% PP) and the others added 2.5% (F2), 5% (F3), 7.5% (F4) and 10% (F5) of PP. The results of sensory analysis indicated the feasibility of adding PP in pineapple jam, especially up to a level of 5%. The addition of PP increased soluble solids, titratable acidity, sugars, moisture, dietary fiber, phenolic compounds and antioxidant capacity. Also, it increased the values for a* and decreased for L* and b*. The use of up to 5% PP in jam should be encouraged as it can improve physicochemical characteristics and maintain sensory acceptability of the product. It also reduces negative effects of organic waste disposal on the environment.

1. INTRODUCTION

Food waste is the food products disposal, which can occur from the beginning of the production chain to the final consumer [1]. On average 1.3 billion tons of food is wasted per year, resulting in approximately 30% of all food production. Roots, fruits, vegetables and oilseeds represent between 40 and 50% of these losses [2]. Brazil is among 10 countries that waste the most food in the world, close to 41 thousand tons. In the case of fruits, 30% of all production does not reach the final consumer's table [3]. After harvest, fruits have a very short shelf life, which leads to nutritional and economic losses. In addition, there is harm to the environment as the disposal of organic waste is increased. It is estimated that the rejection of byproducts from fruits and vegetables (seeds, stems, peel and leaves) can reach 30% in developed countries and 60% in developing countries [4]. However, it is known that it has a high nutritional content, especially bioactive compounds, which may help reduce the risk of cardiovascular disease, cancer and diabetes mellitus [5]. In this regard, there is a growing interest in using byproducts in food products, both by industry, researchers and consumers.

Pineapple (*Ananas comusus*) belongs to the Bromeliaceae family and, is one of the tropical fruits with the highest production in the world, estimated at around 20% [6]. Countries such as Thailand, the Philippines, Indonesia, India, China, Costa Rica, Brazil, Nigeria and South Africa are the largest fruit producers [7]. In 2017, world pineapple production was around 25 million tonnes, while in Brazil about 284,000 tons were produced, corresponding to approximately 11% of all fruit production [8]. In Brazil, most of pineapple production (97%) is destined for fresh consumption, being one of the six most consumed fruits [9]. This fruit has a good nutritional profile, with high levels of vitamins, minerals, fiber, flavonoids and carotenoids [10]. Generally, pineapple can also be consumed dehydrated, canned, as a juices, jams and compotes [7]. After harvesting fruit has a reduced shelf life, which leads to nutritional and economic losses. In addition, peel is also discarded despite having considerable antioxidants levels [11], [12], dietary fiber [12], vitamins and minerals [13]. However, the use of pineapple peel in food preparations as a form of nutritional enrichment has already shown positive results in jams [14], cereal bar [15] and yogurt [16]. The products showed good acceptability [14] and better technological and microbiological characteristics [15], [16]. Given this, the use viability of byproducts of pineapple is demonstrated, which can also contribute to environment preservation.

Commonly, jam is made from fruit pulp cooked, added water and sugar. Sometimes it may also contain citric acid and pectin [17]. Countries like Chile, China, United States, Spain, France, India, Turkey as well as Brazil stand out in jam production. In Brazil, production in 2017 was about 30.1 million tons of the product [18]. In 2016, 4,000 tons of jam were produced, with consumption reaching 3.36 billion tons [19]. Fruits such as grape, apricot, blueberry [20], mango, pineapple [21], strawberry, orange [17] and pomegranate [22] are the most used for jam production. As it is a low cost product and easy to process, storage and transport becomes a good alternative for the addition of unconventional ingredients such as fruit peels. Nevertheless, researches have already shown that replacing fruit pulp with peel in large quantities can reduce sensory acceptability, negatively alter firmness, color [22], elasticity, and final volume [23], in addition to nutritional characteristics of the product [24]. Considering this aspect, the aim of the present research was to evaluate the effect of pineapple peel (PP) addition in pineapple jam on the physicochemical and sensory characteristics.

2. MATERIALS AND METHODS

2.1. ETHICAL ISSUES

The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of Midwest State University, protocol number 2,201,325/2017.

2.2. RAW MATERIAL ACQUISITION

Six and a half kilograms of pineapple (*Ananas comosus*) was used for procedures. Fruits and ingredients were purchased from local shops in Guarapuava, PR, Brazil. Pineapples with better visual appearance were used. The peels were greenish yellow, without imperfections and of medium size (1.3 kg). All fruits were sanitized in running water and sanitized in sodium hypochlorite solution (150 ppm) for 10 minutes and again sanitized in running water. The peel was extracted manually (0.5 cm), with the help of a knife, yielding 1.3 kg. The peel was crushed in a domestic blender (Mondial®, Brazil) to form a homogeneous mass. It was then stored under refrigeration (8 °C) until the jams were prepared.

2.3. JAMS FORMULATIONS

Five pineapple jams formulations were prepared: standard F1 (0% PP) and the others added 2.5% (F2), 5% (F3), 7.5% (F4) and 10% (F5) of PP. These addition levels were defined by preliminary sensory testing performed with the product. In addition to PP, the following ingredients were used in formulations: pineapple pulp (65% (F1), 62.50% (F2), 60% (F3), 57.5% (F4) and 55% (F5)), sugar (34.4%), citric acid (Synth®, Brazil) (0.2%) and pectin (Mago®, Brazil) (0.4%). Fruit pulp and PP were mixed with sugar at room temperature (22 °C), stirring until sugar dissolved. The mixture was heated in domestic stove (Atlas®, Brazil) until boiling (103 °C). Then pectin was added and cooked for further 2 minutes. SS were measured and when they reached the ideal °Brix (63° to 68°) citric acid was added until pH was adjusted (3.30 to 3.40). Mixture was cooked for a further 2 minutes [25]. Jams were bottled still hot (79-85 °C) in 500 ml glass, pasteurized (70 °C) for 30 minutes, cooled to room temperature (22 °C) [26] and stored at room temperature (22 °C) until the analysis time.

2.4. SENSORY ANALYSIS

Sixty-three untrained volunteers participated in sensory analysis, being students, staff and teachers from UNICENTRO, of both genders, aged between 18 and 60 years. The tests were conducted in individual, white-lighted booths. Attributes of appearance, aroma, taste, texture and color and overall acceptance were assessed using a 9-point structured hedonic scale ranging from 1 ("very much disliked") to 9 ("very much liked"). Also, a purchase intention question was applied analyzed using a 5-point structured scale (1 - "would not buy" to 5 – "would buy for sure") [27]. Consumers received 10 g of each sample in disposable white plastic cups (50 mL), coded with three-digit numbers, in a randomized and balanced form, accompanied by a glass of water for palate cleansing. The formulations were offered in a monadic sequence. The Acceptability Index (AI) was calculated according to the formula: AI (%) = A × 100/B (A = mean grade obtained for the product; B = maximum grade given to the product) [28].

2.5. PHYSICOCHEMICAL ANALYSIS

Physicochemical determinations were performed in triplicate in pulp and peel, and in standard jam and in one with the highest percentage of peel and with sensory acceptance similar to standard product. Following evaluations were performed and results were expressed in wet matter: pH, measured by a bench pH meter (Tecnopon®, MPA-210 model, Brazil); SS, obtained by direct reading in ABBE bench refractometer (Bel®, RMI/RMT model, Brazil) [29]. Values were expressed in °Brix; TA using titration method [29]. Results were expressed as citric acid percentage (%); SS/TA ratio, which was obtained by dividing the values between SS and TA; Reducing Sugars (RS), Non-Reducing Sugars (NRS) and Total Sugars (TS) were evaluated by Lane-Eynon reductometric method [29]. Results were expressed as g 100 g^{-1} and Color was analyzed by the Commission of the Commission Internationale de l´Eclairage (CIE) L^* (lightness), a^* (red-green) and b^* (yellow-blue), with colorimeter reading (Konica Minolta®, Chroma Meter CR 4400 model, Tokyo, Japan) with illuminant D65 and angle 10° [30].

The moisture (g 100 g^{-1}), ash (g 100 g^{-1}) and protein (g 100 g^{-1}) contents were evaluated by the Association of Official Analytical Chemists [29] methodology; lipid (g 100 g^{-1}) by Bligh and Dyer [31]; carbohydrate (g 100 g^{-1}) by difference method (% Carbohydrate = 100 − (% moisture + % ash + % protein + % lipid + % fiber); total energy value (kcal 100 g^{-1}) using the values recommended by Atwater and Woods [32] for lipids (9 kcal g^{-1}), protein (4 kcal g^{-1}) and carbohydrate (4 kcal g^{-1}); total and insoluble dietary fiber (g 100 g^{-1}) determined by enzymatic method [29]. Soluble dietary fiber content (g 100 g^{-1}) was calculated by the difference in total and insoluble dietary fiber results; ascorbic acid (Vitamin C) determined by the 2.6 dichlorophenolindophenol titration method [29], modified by Benassi and Antunes [33] and results expressed in mg 100 g^{-1}; phenolic compounds measured by the Folin-Ciocalteu spectrophotometric method [34]. The values was taken on a spectrophotometer (Agillent Technologies®, Cary 60 UV model, Malaysia) at 765 nm and results being expressed as mg of gallic acid equivalent (GAE) 100 g^{-1}; total carotenoids (μg g^{-1}) obtained by spectrophotometric analysis (Agillent Technologies®, Cary 60 UV model, Malaysia) at 450 nm [35]; antioxidant capacity was evaluated by the ABTS method (2,2-azinobis-[3-ethyl-benzothiazolin-6-sulfonic acid]) in both versions hydrophilic with ABTS solution was diluted with acetone 50% and lipophilic with ABTS solution was diluted with methanol 50% [36]. Results were expressed in μmol Trolox 100^{-1} of sample.

2.6. STATISTICAL ANALYSIS

Data were analyzed using software R version 3.6.1 by analysis of variance (ANOVA). The comparison of means was performed by Tukey and Student's t-tests, evaluated with a 5% significance level.

3. RESULTS AND DISCUSSIONS

3.1. SENSORY ANALYSIS

Table 1 describes the sensory scores of jams added with different PP levels. Higher scores for appearance ($p < 0.05$) were found to F1, F2 and F3 formulations. The addition of PP in jams did not affect aroma notes ($p > 0.05$). Higher acceptability for taste, texture and color attributes was observed for formulations F1 and F2, compared to F4 and F5. Also, F3 was better accepted than F5. Samples F1 and F2 scored higher than F4 and F5 considering overall acceptance, while F3, F4 and F5 did not differ significantly ($p > 0.05$). Purchase intention scores were lower for F4 and F5 formulations ($p < 0.05$). Thus, it can be seen that the addition of up to 5% PP in pineapple jam does not interfere with sensory acceptability, corroborating the Younis et al. [24] research that investigated papaya jam with sweet lemon peel flour (5%). The presence of high levels of phenolic compounds in PP (Table 2) may explain the lower grades obtained in samples F4 and F5. When heated, these substances cause an astringency sense in product [37] which impairs acceptability.

Table 1: Sensory scores (mean ± standard deviation) of pineapple jam added with different pineapple peel contents

Parameter	0%	2.5%	5%	7.5%	10%
Appearance	8.0±1.43^{a}	7.7±1.28^{a}	7.2±1.20^{a}	6.3±2.05^{b}	5.8±1.94^{b}
AI (%)	88.3	85.0	80.6	70.3	64.3
Aroma	7.6±1.27^{a}	7.5±1.42^{a}	7.5±1.39^{a}	7.0±1.64^{a}	6.9±1.66^{a}
AI (%)	84.8	83.1	83.2	77.8	77.1
Taste	7.7±1.41^{a}	7.3±1.31^{a}	7.0±1.49^{ab}	6.6±1.93^{bc}	6.1±1.99^{c}
AI (%)	85.6	81.6	77.8	73.8	67.2
Texture	7.3±1.81^{a}	6.6±1.88^{a}	6.3±1.29^{ab}	5.4±2.11^{bc}	4.7±2.33^{c}
AI (%)	80.9	73.7	69.6	59.7	51.9
Color	7.8±1.53^{a}	7.5±1.53^{a}	7.0±1.37^{ab}	6.5±1.83^{bc}	5.8±2.06^{c}
AI (%)	87.1	83.4	78.0	72.1	64.9
Overall Acceptance	7.1±1.99^{a}	7.1±1.65^{a}	6.2±1.69^{ab}	6.1±2.13^{b}	5.4±2.11^{b}
AI (%)	78.9	78.7	69.4	67.9	60.1
Purchase Intention	4.0±1.17^{a}	3.7±1.06^{ab}	3.4±0.90^{ab}	3.2±1.34^{b}	2.7±1.19^{c}

Distinct letters on the same row indicate significant difference in the Tukey's test ($p < 0.05$) for jams: AI: Acceptability Index.

Color is an attribute directly related to food product acceptance. During the jam processing, it was observed that the greater was the addition of peel, the darker was the color. Carotenoid instability at high temperatures [38] may explain this effect. Carotenoids are highly unsaturated compounds and are subject to oxidation and isomeration reactions that decrease biological activity and alter the characteristic color of these compounds [39]. The reaction is favored by the presence of light, heat, metals, enzymes and peroxides [40]. Addition of PP altered the jam texture as it made gel formation difficult, promoting more pasty consistency and formation of fibrous residues in product. In jams made only with fruit pulp, gel formation occurs due to the balance between pectin, sugar and acid contents. With the peel addition, this process is compromised [17], as it contains higher fiber contents than pulp [41], increasing liquid absorption and, consequently, product consistency [42]. In general, peel addition up to 5% in pineapple jam maintained an AI ≥ 70%, which ranks the product with good sensory acceptance [43]. This generally indicates the feasibility of adding PP to the jam, especially up to a level of 5%. Similar results were observed after the use of PP in pineapple jam [44] and PP extract in peach jam [14].

3.2. PHYSICOCHEMICAL COMPOSITION

Considering that sample F3 was the one with the highest PP content and with similar sensory acceptance as standard in all evaluations (Table 1), it was selected for physicochemical comparison purposes along with the standard formulation (F1) presented in Table 2. Higher pH levels were verified for PP while the pulp presented higher Titratable Acidity (TA). Nevertheless, PP addition reduced pH and increased TA in jam (5% PP), as verified by Lago-Vanzela et al. [45] evaluating jam with addition of 'cajá-manga' peel. The peel has higher amounts of polysaccharides in the form of pectin, cellulose and hemicellulose [46]. In acidic solutions, these substances are depolymerized, generating compounds such as xylose, acetic acid, furfural and hydroxymethylfurfural which can be transformed into formic acid [47], increasing the acidity of the product.

Table 2: Physicochemical composition (mean ± standard deviation) of pineapple pulp, peel and jam with added 0% (F1) and 5% (F3)

Parameter	Pineapple pulp	Pineapple peel	F1	F3
pH	3.8±0.01^B	6.3±0.01^A	3.4±0.01^a	3.3±0.02^b
Soluble Solids (ºBrix)	20.0±0.00^A	2.1±0.00^B	63.0±0.00^b	65.0±0.00^a
Titratable Acidity (% citric acid)	7.0±0.04^A	0.6±0.02^B	1.1±0.04^b	1.3±0.02^a
Soluble Solids/Titratable Acidity (ratio)	2.9±0.02^B	3.3±0.08^A	50.6±0.02^a	51.1±0.02^a
Reducing Sugars (g 100 g^{-1})	4.6±0.03^A	3.0±0.02^B	14.3±0.00^b	25.0±0.01^a
Nonreducting Sugars (g 100 g^{-1})	12.1±0.01^B	15.3±0.26^A	21.4±0.01^b	27.6±0.02^a
Total Sugars (g 100 g^{-1})	16.7±0.00^B	18.3±0.0^A	35.7±0.01^b	52.6±0.01^a
*L**	64.7±0.59^A	51.2±0.77^B	32.9±0.83^a	29.7±0.78^b
*a**	-4.5±0.08^B	-2.7±0.43^A	-1.6±0.10^b	-1.1±0.11^a
*b**	18.0±0.53^B	20.7±0.82^A	6.6±0.25^a	4.6±0.34^b
Moisture (g 100 g^{-1})	85.4±0.06^A	84.9±0.05^B	20.9±0.03^b	32.7±0.07^a
Ash (g 100 g^{-1})	0.3±0.03^B	0.7±0.02^A	0.3±0.07^a	0.3±0.08^a
Protein (g 100 g^{-1})	0.7±0.05^B	0.8±0.04^A	0.3±0.06^a	0.4±0.09^a
Lipid (g 100 g^{-1})	0.0±0.06^B	0.1±0.04^A	0.1±0.09^a	0.1±0.04^a
Carbohydrate (g 100 g^{-1})*	13.6±0.45^A	13.6±0.86^A	78.4±0.56^a	66.6±0.23^b
Total energy value (kcal 100 g^{-1})	57.3±0.69^A	58.1±0.98^A	315.8±0.64^a	268.3±0.76^b
Soluble fiber (g 100 g^{-1})**	0.0±0.11^B	0.3±0.09^A	0.1±0.15^a	0.1±0.11^a
Insoluble fiber (g 100 g^{-1})**	0.8±0.13^B	5.1±0.10^A	0.5±0.10^b	0.7±0.12^a
Total fiber (g 100 g^{-1})**	0.8±0.10^B	5.4±0.14^A	0.6±0.16^b	0.8±0.15^a
Total carotenoid (μg g^{-1})	24.9±0.03^A	10.9±0.01^B	3.1±0.06^a	2.9±0.01^b
Ascorbic acid (mg 100 g^{-1})	120.8±0.02^A	6.3±0.06^B	13.5±0.12^a	12.8±0.48^b
Phenolic compounds (mg GAE 100 g^{-1})	5.6±0.03^B	39.8±0.03^A	35.9±0.01^b	40.5±0.03^a

Distinct letters in row are significantly different by the Student's t-test ($p < 0.05$), considering capital letters for the differences between pulp and peel and lowercase letters for the jams; Results reported in wet weight basis; *not include dietary fiber; **dietary fiber.

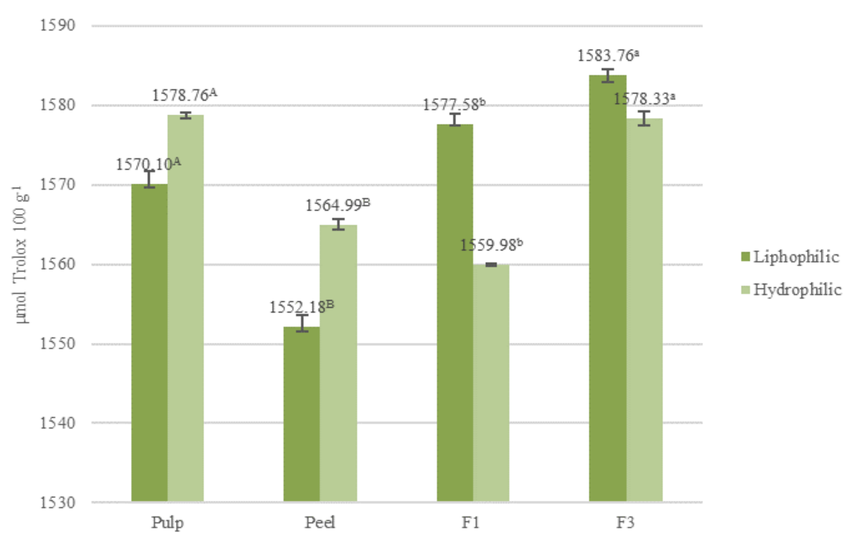
Soluble Solids (SS) content together with TA (SS/TA) is one of the most efficient methods for demonstrating the degree of fruit maturity and taste. Generally, products with higher SS content and lower TA present greater sweetness and acceptability [48]. Although pineapple pulp had higher SS content and lower SS/TA ratio than peel ($p < 0.05$), the jam containing PP had higher SS concentration and SS/TA ratio similar to F1. During cooking, polysaccharides hydrolysis (pectin, cellulose and hemicellulose) occurs [49] present in peel, which results in glucose and fructose formation [50]. In addition, pectin is present in higher concentration in peel (2.49 g 100 g^{-1}) [49] compared to pulp (91.08 mg 100 g^{-1}) [51]. This fiber has hydrophilic groups that absorb water, which concentrates SS [52], corroborating to literature [45].

Pulp presented higher Reducing Sugars (RS) (glucose and fructose) and lower Nonreducting Sugars (NRS) (sucrose) and Total Sugars (TS) contents in relation to peel. In peel, the RS are responsible for the fruit protection [53]. During ripening, starch is converted into glucose and fructose, which are used in stressful situations, such as at low temperatures, for example, which explains the lower RS content in peel [53]. The peel addition to jam increased RS, NRS and TS concentration. Cooking in an acid medium promotes sucrose degradation, present in higher amounts in peel, in glucose and fructose [54], which increases the RS concentration in jam.

Higher values for L* and lower than a* and b* were found in pineapple pulp when compared to peel. Pulp and peel a* values were negative, which demonstrates a greenish color. Similar results were observed in pineapples grown in Thailand [55]. In the case of pineapple, one of the most common methods for analyzing ripeness is the changing of the peel color from green to yellow [10]. In jam, the addition of PP increased the value of a* and decreased the values of L* and b*, as it has lower brightness and higher red content than pulp. This is due to the presence of higher chlorophyll content present in pineapple peel (232.13 µg g^{-1}) compared to pulp (152.12 µg g^{-1}) [56], since when degraded it has a greenish brown color [57]. In general, jams can be considered dark in color, as L* values were less than 50%, with a yellow tone (b*) and a green sub-tonality (a*).

Pulp had higher moisture content compared to peel, since it has high water content (85-86%) [10]. However ash, protein, lipid and fiber contents were higher for the peel, as these compounds have protective function, preventing oxidation [58], mechanical damage [59] and action of microorganisms [60]. There was no significant difference ($p > 0.05$) between carbohydrate and calorie contents between pulp and peel. The addition of PP increased moisture content in jam ($p < 0.05$) due to its higher fiber content, which has high hygroscopic content [57]. There was no significant difference ($p > 0.05$) between jams for ash, protein and lipid contents. However, the PP use in jam reduced carbohydrate and calorie content and increased fiber content as found by Damiani et al. [61] in jelly with mango peel addition (0 to 100%).

Pineapple pulp presented higher levels of total carotenoids and ascorbic acid which consequently reduced the content of these compounds in F3 ($p < 0.05$). Although pineapple pulp had approximately 19 times more vitamin C than the peel, the difference in vitamin content between F1 and F3 was small. Compounds such as flavonoids, present in larger quantities in peel (211.20 mg QE 100 g^{-1}) [62] than in pulp (26.20 mg GAE 100 g^{-1}) [63], prevent the vitamin C degradation, as they are potent antioxidants. Pineapple peel presented higher levels of phenolic compounds than pulp, which significantly increased phenolic content in jam.



Distinct letters in column are significantly different by the Student's t-test ($p < 0.05$), considering capital letters for the differences between pulp and peel and lowercase letters for the jams; Results reported in wet weight basis.

Figure 1: Lipophilic and hydrophilic mean antioxidant capacity of pineapple pulp, peel, and jam with added 0% (F1) and 5% (F3).

Figure 1 shows results of the antioxidant capacity for pulp and peel pineapple and standard jam (F1) and added with 5% (F3) of PP. Higher antioxidant capacity was observed in pulp compared to PP ($p < 0.05$), since the pulp has higher amounts of ascorbic acid and carotenoids than the peel. However, PP addition increased antioxidant capacity in jam, similar to that observed by Damiani et al. [61]. This effect occurs due to the high cooking temperature, promoting the hydrolysis of vacuoles [49] and lipid membranes [64] present in peel cell wall. This results in release of a significant content of phenolic compounds [65] and carotenoids [64] in jam.

4. CONCLUSIONS

A level up to 5% addition of pineapple peel in jam is well accepted by consumers, achieving sensory acceptance similar to standard product. Moreover, it improves physicochemical profile of the product with increased antioxidant capacity and soluble solids, titratable acidity, sugars, fiber and phenolic compounds, with reduced carbohydrate and calorie content. The use of jam byproducts should be encouraged as it can improve their physicochemical characteristics and maintain sensory acceptability. It also reduces the negative effects of organic waste disposal on the environment.

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CONFLICT OF INTEREST

The author have declared that no competing interests exist.

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