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Effect of Fermented Feed on Nutrient Apparent Digestibility of Piglets

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ABSTRACT

In order to analyze the effect of fermented feed on the production performance, slaughter performance, digestion and metabolism of nutrients and economic benefits of piglets, this paper analyzes the effect of fermented feed (taking grape pomace residue as example) on the nutrient apparent digestibility of piglets. Through the determination of tannin content in grape pomace residue, the nutritional value of grape pomace residue was evaluated, and the influence of feed with different grape pomace residue content on the nutrient apparent digestibility of piglets was analyzed, which provided scientific basis for the rational development and utilization of grape pomace residue and pig breeding. The results showed that grape pomace residue had a promotion effect on the nutrient apparent digestibility, production performance, slaughter performance, digestion and metabolism of nutrients and economic benefits of piglets, so it is an ideal feed material of piglets.

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XL, ZZ, LZ and CP collected the samples. JH and FL analysed the data. JL and CP conducted the experiments and analysed the results. All authors discussed the results and wrote the manuscript.

Key words
Grape pomace, Piglets, Fermented feed, Apparent digestibility

INTRODUCTION

The analysis of the effect of fermented feed on the nutrient apparent digestibility of piglets is of importance for the scientific feeding of pigs. At present, fermented feed has been widely used (Lanzi *et al*., 2020; Chacar *et al*., 2018; Šporin *et al*., 2018). Grape peel dregs contain many kinds of plant functional ingredients. Grape juice is the main form of grape processing products. However, only part of the effective components are transferred to grape juice or wine during the process of juicing and brewing, and most of the beneficial plant components are discarded along with grape skin residue (Carmona *et al*., 2018; Ebrahimzadeh *et al*., 2018). Grape pomace residue mainly include polyphenols, tartrate (Xu *et al*., 2019; Yan *et al*., 2019; Yeh *et al*., 2018) and grape pomace cellulose (Mudronová *et al*., 2018; Fan *et al*., 2018) and other beneficial components. In the apparent digestibility, nitrogen metabolized from feces in the nitrogen free diet is regarded as the undigested part, but in fact it is the part metabolized from feces after digestion, so the true digestibility is greater than the apparent digestibility. Based on the above analysis, this paper evaluates the nutritional value of grape pomace residue by measuring the tannin content in grape pomace residue, and analyzes the effect of feeds with different contents of grape pomace residue on the nutrient apparent digestibility of piglets, so as to provide some scientific data for the rational development and utilization of grape pomace residue and offer references for pig breeding.

MATERIALS AND METHODS

Determination of tannin content in grape residue

In this experiment, 104 bags of grape residue were determined, each bag weighs 50kg ± 2kg. Because of the difference in tannin content among bags of grape residue, three samples were taken from each bag, and mixed by quartering method.

In this experiment, 70% acetone diluted tannin and 0.50mL of extract were added in a 100 × 12mm glass tube with a cover (the amount of acetone should be large enough to prevent the absorbance from exceeding 0.6. This amount is about the expected content of condensed tannin in the sample). Then, 3.0mL of butanol hydrochloric acid reagent and 0.1mL of prepared iron reagent were successively added in the test tube before covering the test tube cover. After that, the solution in the test tube was

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subjected to vortex shaking, treated in a boiling water bath of 97 °C ~ 100 °C for 60min, cooled down for observation of the color at the wave length of 550nm.

The results show that the content of grape seed tannin is 4.55%, the content of condensed tannin is 2.88%, the content of grape skin tannin is 1.52%, the content of condensed tannin is 0.67%.

Test design

In this experiment, the single factor experiment design was adopted. Four diets were randomly designed, namely I as the basic diet, II, III and IV as the basic diet containing 8%, 16% and 24% grape residues (the ratio of grape skin and grape seed is 1:1.22). Grape skin and grape seed were separated by natural wind, and separately packed into different woven bags and added to the diet separately.

Diet formula

According to the 0.9-fold test design of Chinese piglet feeding standard NRC piglet fattening nutritional requirement (2010), the nutritional requirement of adult pigs with a weight of 30 kg and a daily gain of 0.1 kg / D was formulated (Table I).

Experimental animals and feeding management

Sixty Yorkshire and Yantai black Hybrid Pigs, which were weaned at about 3 months old were selected as research subjects for the experiment. The transition period was 20 days, the pre-trial period was 10 days, and the normal trial period was 60 days. During the transition period and the pre trial period, each piglet was fed with diet I three times a day at 8:00, 14:00 and 19:00, respectively. The feed intake of each piglet was accurately recorded.

Effect of grape residue level on production and slaughter performance of piglet

At the end of feeding experiment, 10 piglets with live weight close to the average value of the group were selected from each group. After 24-h feeding prohibition and 2-h water prohibition, slaughtering was completed within one day, and the level of meat production was measured.

Daily intake of dry matter: record the feed amount of each pig every day, then subtract the last remaining feed amount from the feed amount, and calculate the average daily intake of dry matter of each piglet in each group.

Average daily gain%: (test end weight-test start weight)/ test days × 100.

Feed conversion rate: the ratio of the weight of air dried feed consumed 1kg to the weight of the unit animal product obtained.

Table I. Diet formula (air drying basis).

	I	II	III	IV
Feed material				
Corn	25.00	30.00	31.20	34.00
Malt root	3.00	2.00	1.00	1.00
Flaxseed meal	4.00	2.00	1.00	1.00
Soybean meal	4.00	2.00	2.00	1.00
Cottonseed meal	2.00	2.00	2.00	1.00
Barley straw	45.00	25.50	24.30	14.50
Silage corn	9.50	21.00	15.00	16.00
Grape dregs	0.00	8.00	16.00	24.00
Alfalfa	5.00	5.00	5.00	5.00
Ammonium sulphate	0.70	0.70	0.70	0.70
Urea	0.80	0.80	0.80	0.80
Salt	0.50	0.50	0.50	0.50
Mineral premix	0.40	0.40	0.40	0.40
Vitamin premix	0.10	0.10	0.10	0.10
Total	100.00	100.00	100.00	100.00
Nutritional level				
Digestive energy	11.20	11.20	11.20	11.20
Crude protein	12.00	12.00	12.00	12.00
Calcium	0.42	0.42	0.42	0.42
Phosphorus	0.20	0.20	0.20	0.20
Neutral washing fiber	43.20	42.70	42.00	41.80
NDF				
Ratio of fineness to coarseness	4:6	4:6	4:6	4:6
Condensed tannins	0.00	1.50	3.00	4.50

Note: * amount of common elements added (mg·kg^{-1}): S 200; Fe 25; Zn 40; Cu 8; I 0.3; Mn 40; Se 0.2; Co 0.1. *Vitamin dosage (IU·kg^{-1}):VA 940; VE 20. In addition, the composition and nutritional level of all raw materials in the diet were measured.

Slaughter rate %: carcass weight/ live weight before slaughter × 100.

Net meat rate: the ratio of net meat amount to live weight.

GR value: the tissue thickness between the 12th rib and the 13th rib, 11cm away from the midline of the back ridge, which represents the index of carcass fat content, was measured by vernier caliper.

Effects of different grape residue levels on nutrient digestion and metabolism of piglets

During the metabolism test, about 200g feed samples were collected every day. The feed samples during the whole test were evenly mixed by the quartering method. Under the natural wind condition, the feed samples were dried and crushed, before passing through 40 mesh sieve, and stored in the refrigerator at room temperature for testing at 4 ℃.

Three days before the pre feeding period, the test pigs were tied to the fecal bags normally to grasp the tightness of the bags accurately. On the day before the start of the trial period, the fecal bag was fastened. The daily feeding quantity and remaining quantity were recorded accurately. Before urine collection, 5mL of concentrated H_2SO_4 was added into the urine collection bucket every day (ensure the pH value of urine is below 2). The fecal samples and urine samples were collected regularly every day, and the fecal output and urine output were recorded. Moreover, 0%-20% of the daily fecal samples of each pig (the proportion of fecal samples collected from each pig is the same) was placed into an aluminum box, dried at 65-70℃ to constant weight, transferred into a sampling bag for sealing and preservation before measuring the conventional nutrients such as DM (dry matter quality), OM (organic matter), Ca (calcium), P (phosphorus), CP (crude protein), NDF (neutral detergent fiber) and ADF (acid detergent fiber). Another 5% of the fecal sample was added into a jar, followed by addition of a proper amount of 10% H_2SO_4 solution (just immerse the fecal sample completely), and transferred into a refrigerator (4 ℃) for preservation. The fecal samples of 6 days were made into mixed samples for the determination of fecal nitrogen. The urine collecting bottle was put into the refrigerator for urine determination.

Statistical analysis of data

SPSS17.0 statistical analysis software was used for data processing. Tukey method was used for multiple comparison when there were significant differences between groups. The test data was expressed in the form of average value ± standard deviation.

RESULTS AND DISCUSSION

Table II shows the effect of different levels of grape residue in diets on performance and slaughter performance of piglet.

Piglet performance

The level of grape residue had a significant effect on the performance of piglets (Table III, $P < 0.05$). The daily feed intake, total weight gains and daily gain of piglets in group II, III and IV were significantly higher than those in group I ($P < 0.01$), while the daily feed intake and daily gain of piglets in group III were the highest, but there was no significant difference among the three groups ($P > 0.05$); the feed conversion rate of piglets in group II was significantly higher than that in group I ($P < 0.05$).

It can be seen from Table IV that the live weight before slaughter, carcass weight, net meat weight, slaughter rate and GR value of piglets in groups II, III and IV were significantly higher ($P < 0.05$) or extremely higher ($P < 0.01$) than those in group I, the visceral fat weight of piglets in group IV was significantly higher than that in group I ($P < 0.05$), and the net meat rate and back fat weight of piglets in group II were significantly higher ($P < 0.05$) or extremely higher ($P < 0.01$) than those in group I.

In this experiment, the piglets were not mature at the time of slaughter, the slaughter rate was between 45.99%-49.5%, and the net meat rate was between 31.38%- 35.75%. Compared with the control group, the piglets in the test group with larger live weight had better slaughter rate. The net meat rate of group II was significantly higher than that of the control group, indicating that the 8% grape residue group had the best level of meat production. The larger live weight is the higher fat deposition ability is. The higher the carcass weight and the greater the carcass thickness, the higher the meat to bone ratio. In summary, an appropriate level of grape residue significantly improved the slaughter performance and ketone body size of piglets.

Table II. Effects of different levels of grape residue in diets on performance and slaughter performance of piglet.

Project	I (Basic diet)	Basic diet + grape residues			P value
		II (8%)	III (16%)	IV (24%)	
Initial weight of pre feeding period	24.32±2.75	24.22±2.48	24.34±2.58	24.24±2.68	0.999
Initial weight of normal trial period	25.39±2.58	25.29±2.94	25.39±2.58	25.26±3.34	0.999
Final weight of normal test	30.75±4.39	34.10±4.51	34.23±3.78	33.89±3.62	0.123
Total weight gain	$5.56±1.94^{B}$	$8.61±2.34^{A}$	$8.91±2.01^{A}$	$8.00±2.63^{A}$	0.002
Daily gain	$87.17±28.40^{B}$	$140.49±37.62^{A}$	$142.9±30.93^{A}$	$136.89±37.64^{A}$	0.000
Daily intake	$0.93±0.09^{B}$	$1.08±0.11^{A}$	$1.21±0.14^{A}$	$1.15±0.22^{A}$	0.000
Feed conversion	$9.41±2.52^{b}$	$12.70±2.43^{a}$	$11.41±3.24^{ab}$	$11.22±2.70^{ab}$	0.022

Note: there is a significant difference between the numbers in the same industry ($p<0.05$), and there is a significant difference between the numbers in the same industry ($p<0.01$).

Table III. Effect of grape residue level on slaughter performance of piglets.

Project		Basic diet + grape residues			P value
	I (Basic diet)	II (8%)	III (16%)	IV (24%)	
Live weight before slaughter	27.06±1.99^{b}	30.39±3.24^{a}	31.33±3.60 ^{a}	31.11±3.40 ^{a}	0.015
Carcass weight	12.45±1.24^{B}	14.78±2.13^{A}	15.07±2.11 ^{A}	14.39±2.11 ^{A}	0.005
Slaughter rate	45.99±2.90^{b}	48.53±2.82^{a}	49.50±2.03 ^{a}	48.20±2.72 ^{a}	0.017
Net meat weight	8.44±0.31^{B}	10.84±1.35^{A}	10.44±1.70 ^{A}	10.47±170 ^{A}	0.001
Net meat rate	31.18±2.81^{B}	35.75±3.44^{A}	33.34±2.09^{AB}	34.33±2.35^{AB}	0.005
Visceral fat weight	0.17±0.12^{b}	0.27±0.14a^{b}	0.27±0.13^{ab}	0.34±0.11 ^{a}	0.027
Back fat weight	140.19±22.85^{b}	201.66±52.02^{a}	172.98±44.23^{ab}	173.93±45.29^{ab}	0.030
GR value	7.19±1.27^{B}	10.09±2.83^{A}	10.44±1.99^{A}	10.19±1.85^{A}	0.001
Bone weight	3.44±0.50	3.87±0.46	3.96±0.79	3.67±0.37	0.172
Bone to meat ratio	2.48±0.35	2.81±0.33	2.68±0.32	2.85±0.35	0.085

Table IV. Effect of adding different level of grape residue on DM and OM.

Project	I (Basic diet)	Basic diet + grape residues			P value
		II (8%)	III (16%)	IV (24%)	
Ingestion	0.79±0.054^{b}	0.88±0.12^{ab}	0.92±0.08 ^{a}	0.97±0.11 ^{a}	0.023
Excretion of fecal DM	0.22±0.05	0.22±0.04	0.27±0.05	0.27±0.05	0.100
DM digestibility	0.58±0.03^{b}	0.66±0.08 ^{a}	0.66±0.03 ^{a}	0.65±0.71 ^{a}	0.010
Apparent digestibility of DM	72.78±4.75	75.14±19.66	71.27±3.28	72.06±2.47	0.235
Om intake	0.73±0.05 ^{b}	0.81±0.11^{ab}	0.85±0.07 ^{a}	0.90±0.11 ^{a}	0.014
Excretion of excrement OM	0.19±0.04	0.19±0.04	0.24±0.42	0.35±0.25	0.157
Om digestibility	0.54±0.02^{B}	0.61±0.07 ^{B}	0.61±0.03 ^{B}	0.70±0.10 ^{A}	0.003
Apparent digestibility of OM	74.15±4.53	76.27±1.90	72.47±3.11	75.12±5.21	0.406

Table V. Effect of adding different level of grape residue on N apparent digestibility.

Project	I (Basic diet)	Basic diet + grape residues			P value
		II (8%)	III (16%)	IV (24%)	
N intake	104.79±7.51	114.87±15.02	112.45±9.80	122.55±14.39	0.135
Fecal N excretion	37.27±7.05^{b}	46.07±4.73^{ab}	46.42±17.21^{ab}	50.85±10.30^{a}	0.041
Urine N excretion	29.91±6.10^{A}	24.63±5.67^{A}	17.61±5.93^{AB}	14.19±6.41^{B}	0.007
N digestibility	66.96±5.23	67.16±11.65	64.56±6.79	69.69±7.41	0.559
N apparent digestibility	62.61±2.41^{a}	61.95±3.02a^{b}	57.54±4.85^{ab}	56.98±3.11^{b}	0.038
N apparent retention	35.88±3.34^{b}	48.91±9.93^{b}	48.42±2.92^{b}	58.52±6.33^{a}	0.014
N apparent retention rate	34.17±3.1^{B}	41.82±4.3 ^{A}	42.85±6.6 ^{A}	48.50±4.90^{A}	0.002

Feeding 8% (CT content is 1.5g.kg-1), 16% (CT content is 3.0g.kg-1) and 24% (CT content is 4.5g.kg-1) grape residue had a significant effect on growth performance and slaughter performance of piglets. The feed conversion rate, carcass weight, slaughter rate and GR value of piglets fed with grape residue were significantly higher than those of the control group. The feed conversion rate, net meat rate and back fat weight of 8% grape residue group were significantly higher than those of the control group.

Apparent digestion of DM and OM in piglets

Table V shows that the DM and OM intake of group II and IV were significantly higher than those of group I ($P < 0.05$), and the DM digested by group II, III and IV were

significantly higher than that of group I ($P < 0.05$).

Om digested in group IV was significantly higher than that in groups I, II and III ($P < 0.01$). The other differences were not significant ($P > 0.05$).

Apparent digestion and retention of N in piglets

The urinary N excretion of group IV was significantly higher than that of group I ($P < 0.01$) (Table VI), the apparent digestibility of group I was significantly higher than that of group IV ($P < 0.05$), the apparent N retention of group IV was significantly higher than that of groups I, II and III ($P < 0.05$), and the apparent N retention of groups II, III and IV was significantly higher than that of group I ($P < 0.01$). There was no significant difference in the other groups ($P > 0.05$).

ADF and NDF apparent digestion of piglets

The ADF excretion of group IV was significantly higher than that of group I and group II ($P < 0.05$), and the ADF apparent digestibility of group I was significantly higher than that of group IV ($P < 0.05$) (Table VII). Tannin also increased the NDF excretion of piglet manure ($P = 0.063$). There was no significant difference in the other groups ($P > 0.05$).

Apparent digestion of Ca and P in piglets

Table VI shows that feeding different levels of grape residue had no significant effect on the amount of Ca ingested, fecal Ca excretion, CA digestibility, CA apparent digestibility, P ingestion, fecal P excretion and P apparent digestibility ($P > 0.05$).

The P digestibility of group III and IV was significantly higher than that of group I ($P < 0.05$). The other differences were not significant ($P > 0.05$).

The apparent digestibility of some nutrients and the apparent retention of N in the control group were significantly higher than those in the 24% grape residue group, and the apparent digestibility of N and ADF in the 8%, 16%, 24% grape residue groups were significantly higher than those in the 24% grape residue group. With the increase of tannin content, the apparent digestibility of NDF, ADF and N decreased linearly. Considering daily gain, feed conversion rate and nutrient utilization rate, the optimal adding amount of grape residue for piglet is 8% - 16%.

Table VI. Effect of different levels of grape residue on the apparent digestibility of NDF and ANF.

Project	I (Basic diet)	Basic diet + grape residues			P value
		II (8%)	III (16%)	IV (24%)	
NDF intake	404.21±30.62	406.82±54.75	433.49±37.81	434.04±36.21	0.904
Fecal NDF discharge	136.06±28.32	139.82±26.87	167.96±33.80	174.49±22.55	0.063
NDF digestibility	268.15±16.13	274.42±25.56	265.53±15.79	260.76±30.43	0.739
NDF apparent digestibility	66.57±5.40	65.85±2.48	62.42±5.54	61.77±3.31	0.439
ADF intake	227.66±17.52	236.22±31.96	245.29±21.68	256.51±30.50	0.287
ADF excretion of feces	83.1±21.02^{b}	89.89±15.62^{b}	107.75±18.20^{ab}	118.36±22.41^{a}	0.020
ADF digestibility	144.55±11.99	146.32±17.20	137.54±11.83	139.71±20.59	0.754
ADF apparent digestibility	63.81±7.19^{a}	62.09±1.88^{ab}	56.28±5.27^{ab}	53.87±6.34^{b}	0.017

Table VII. Effect of grape resiude level on apparent digestibility of Ca and P.

Project	I (Basic diet)	Basic diet + grape residues			P value
		II (8%)	III (16%)	IV (24%)	
Ca intake	3.54±0.36	3.97±0.58	4.15±0.45	4.40±0.60	0.051
Excretion of fecal Ca	2.26±0.45	2.16±0.43	2.63±0.56	2.91±0.52	0.059
Cadigestibility	1.27±0.47	1.81±0.24	1.52±0.33	1.48±0.29	0.091
Apparent digestibility of Ca	39.61±9.91	45.81±4.31	36.98±9.33	33.87±6.10	0.079
P intake	1.89±0.14	2.00±0.26	2.18±0.18	2.23±0.25	0.075
Excretion of fecal P	0.75±0.11	0.75±0.14	0.82±0.17	0.82±0.18	0.801
P digestibility	1.15±0.08^{b}	1.30±0.14^{ab}	1.34±0.11^{a}	1.39±0.17^{a}	0.029
P apparent digestibility	60.05±3.64	64.12±2.50	61.97±6.00	62.75±5.86	0.525

Table VIII. Feed formula and cost of each group.

Project	Control group	A	B	C
Corn	55	55	55	55
Peanut vermicelli	20	15	12	10
Cottonseed cake	15	10	9	7
Bran	7	2	1	0
Domestic fish meal	1	1	1	1
Bone meal	1	1	1	1
Shell powder	0.5	0.5	0.5	0.5
Salt	0.5	0.5	0.5	0.5
Grape skin dregs	0	15	20	25
Cost	0.76	0.72	0.70	0.68

Unit: %, yuan/kg

Trial feeding test

Trial feeding mode

Each group was fed three times a day. The material water ratio was 1:2-2.5. Raw feed was soaked in cold water. Water was supplied by another sink in the house, and special person was appointed to feed.

Trial feed formula

The experimental feed formula was divided into three groups, namely group A, B, C, as shown in VIII. It can be seen from table 8 that the formula meets the professional standard of mixed feed for growing piglets.

Result analysis

To analyze the feeding effect of fermented grape pomace residue, piglets were weighed from the beginning to the end of trial feeding. See the Table IX for the data.

It can be seen from Table IX that the daily weight gain of group A was more than that of the control group by 3.2%; the daily weight gain of group B was higher than that of the control group by 7.7%; and the daily weight gain of group C was higher than that of the control group by 8.7%. During the test, each group was weighed and the feed to meat ratio was calculated, as shown in the Table X.

From Table X, it can be seen that the meat ratio of group A, B, C was smaller than that of the control group, indicating that the feeding of fermented grape skin residue can save material.

According to the trial feeding situation, cost accounting and economic benefit analysis were carried out, and the results are shown in the Table XI.

It can be seen from Table XI above that compared with control group, the economic benefit of group A, B, C was increased by 19.6%, 40.7% and 47.3%, respectively. By adding 15% ~ 25% fermented grape pomace to feed instead of cottonseed cake and bran, the average income of each pigletcan be increased by 30.7 yuan, the income can be increased by 15350 ~ 30700 yuan, which brings significant economic benefits to pig raising.

Table IX. Weight gain of trial feeding pigs.

Project	Control group	A	B	C
Average initial body weight	29.6	29.8	30.6	29.9
Average body weight	99.6	102.2	106.0	106.0
First day weight gain	0.470	0.485	0.506	0.511
Average head gain	70.0	72.2	75.4	76.1

Unit: kg

Table X. Feed to meat ratio of experimental pigs.

Project	Control group	A	B	C
Average head consumption	242.6	246.8	249.1	252.9
Average head gain	70.0	72.2	75.4	76.1
Meat ratio	1:3.47	1:3.42	1:3.30	1:3.32

Unit: kg

Table XI. Economic benefits of each group.

		Control group	A	B	C
Income	Head gain	70.0	72.2	75.4	76.1
	Unit Price	4.60	4.60	4.60	4.60
	Total	322.0	332.12	346.84	350.06
	Pig manure	8.0	8.0	8.0	8.0
	Total	330.00	340.12	354.84	358.06
Expend-iture	Material consumption	242.6	246.8	249.1	252.9
	Unit Price	0.76	0.72	0.70	0.68
	Total	184.38	177.70	174.37	171.97
	Other	60.0	60.0	60.0	60.0
	Total	244.38	237.70	234.37	231.97
Profit	Profit	85.62	102.42	120.47	126.09
	Top 10 profit	856.2	1024.2	1204.7	1260.9
	Compared with the control group	0	168.0	348.5	404.7
	Increase of efficiency	0	19.6	40.7	47.3

Unit: kg/ yuan, kg/ head, %, yuan/ kg

CONCLUSION

According to the analysis of the daily gain, feed conversion rate, slaughter performance and nutrient utilization rate of the trial piglets fed with grape pomace residue, it can be known that that grape pomace residue has a promotion effect on the nutrient apparent digestibility, production and slaughter performance, digestion and metabolism of nutrients, and economic benefits of piglets. Moreover, the optimal content of grape residue in piglets' diet is 8% - 16%. In this paper, the nutritional value of grape residue was further evaluated, which provides a scientific basis for the rational use of grape residue in animal husbandry. However, further researches on the application of grape residue in production are needed.

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Statement of conflict of interest

The authors have declared no conflict of interest.

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