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EFFECTS OF PROCESSING METHODS ON THE QUALITY OF BLACK PEPPER (*PIPER NIGRUM* L.)

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BIRUK HIRKO[1*], *HAIMANOT MITIKU*[2], *ABUKIYA GETU*[1]

[1]Ethiopian Institute of Agricultural Research (EIAR), Tepi Agricultural Research Center P.O.Box 34, Tepi, Ethiopia
[2]Ethiopian Institute of Agricultural Research (EIAR), Debrezeit Agricultural Research Center, P.O.Box 32, Debrezeit, Ethiopia
**Corresponding author*: birukhirko@gmail.com

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SUMMARY

The quality of black pepper (Piper nigrum L.), the 'king of spices', is largely dependent on the postharvest handling and processing methods. Pungency and aroma are the most important qualities of black pepper, which are attributed to its oleoresin and volatile oils, respectively. Conventional open sun drying and shade drying were tested for different pretreatment curing of black pepper. The quality improvement and reduction in drying duration were exhibited for the sun-dried samples. The highest oleoresin content (8.15% w/w) was recorded in direct open sun-dried samples, whereas in shade-dried samples it was as low as 6.96% w/w. The highest essential oil content of 2.00 mL/100g (v/w) was obtained from the berries blanched for 2 minutes and sun-dried samples. Blanching followed by direct sun drying of berries had the highest acceptability score relative to the overall quality. Therefore, the physicochemical quality analyses performed proved that blanching and sun drying are effective in producing high-quality black pepper for export.

Key words:
black pepper,
blanching,
drying methods,
curing,
quality

INTRODUCTION

Considered the 'king of spices', black pepper (*Piper nigrum* L.) belongs to the family Piperaceae. It is a perennial woody climbing liana widely produced in tropical areas. It is commonly used for flavoring different types of cuisines worldwide (Mathew et al., 2001; Srinivasan, 2007). Black pepper end products include pepper powder, oil, and oleoresin. Black pepper oil and oleoresin are extracted for increased quality, the need of its flavor, and inconsistency in the physicochemical quality of raw materials (Zachariah & Parthasarathy, 2008). It takes six to eight months from flowering initiation until harvesting. Harvesting is done usually during the months of December to February for lowland crops and January to April for hill-grown pepper. Postharvest technology has an extreme role in the quality maintenance of spices (Pruthi, 1993; Purseglove et al., 1981).

The green color of pepper berries converts into black color due to the enzymatic browning by fermentation and oxidization of phenolic compounds (Dhas & Korikanthimath, 2003). Green pepper berries are generally blanched in hot water (80 °C) for 1-2 minutes in producing black pepper for a uniform black color, as well as better flavour quality and aroma (CFTRI, 1980; Ravindran, 2000). Blanching tremendously increases the drying speed of pepper, which can be accounted for by damaging the cell wall of pepper and then enhancing water movement (Kaymak-Ertekin, 2002). Prior to drying, pre-treatments are conducted for achieving best-quality dried herbs, shortening the drying duration, and lowering the energy intake (Deng et al., 2019). The use of the best pre-treatment methods could

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create a simple difference in pepper drying by reducing the cost of processing through minimizing the time of drying (Rooy, 2012).

Black pepper essential oils are widely known for possessing antioxidant and antibacterial properties, as well as anti-oncogenic potential (Misharina et al., 2009; Butt et al., 2013; Zarringhalam et al., 2013). Black pepper postharvest technology includes different operations after harvestings, such as curing, drying, cleaning or garbling, packaging, and storage. Advances in postharvest technology could offer alternative processing methods for spices such as black pepper, which could enhance its physical and biochemical quality. Black pepper is usually harvested and processed traditionally under variable sanitary conditions. Such type of processing results in low-quality products with poor oleoresin and aroma, resulting in low market price in Ethiopia. Furthermore, blanching has not practiced in South Western Ethiopia over the past years. Therefore, the purpose of this study is to determine the effects of blanching and drying methods on the physicochemical quality of black pepper.

MATERIAL AND METHODS

Plant materials

Matured black pepper of the 'Gacheb' cultivar (in the process of turning to yellow from fully-mature green spikes) was obtained from the Tepi Agricultural Research Centre station, Ethiopia. A total of 82.50 kg of black pepper samples were collected in January 2017 and 2.50 kg of black pepper were used for each experimental unit in triplicate.

Processing and measurements

The picked black pepper products were divided into two portions and used individually or in combination to obtain an experimental unit (Fig. 1). One portion contained berries detached from spikes, and another portion contained intact spikes with berries. The samples for hot water treatments were obtained by immersing in hot water at 80 °C for 2 minutes, following the methods described by Pruthi (1992). Conventionally, matured green berries are directly sundried to produce black pepper. Such samples were used as a control against blanching method and were directly taken to sun drying (27-32 °C) or shade drying (23-27 °C). Sweating was done for 1-2 days at 25-30 °C and RH 80-90%.

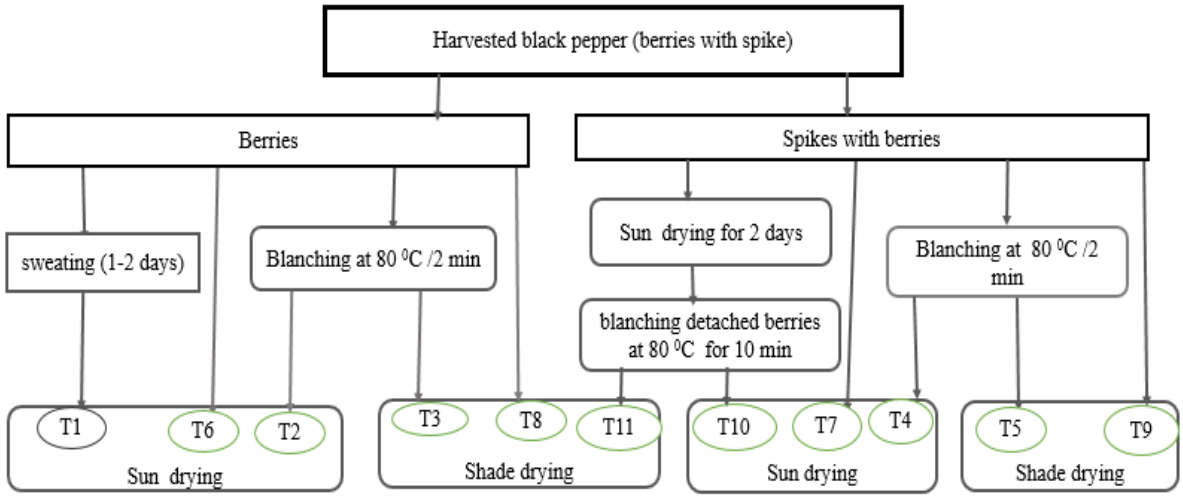


Figure 1. Process applied to black pepper - sweating at 25-30 °C and RH 80-90%

Differently treated black pepper samples were dried using open sun and shade drying methods, placed on a metallic wire mesh stand (1 m above the ground) with 70 cm × 50 cm tray length and width, respectively. The samples (2.50 kg for each drying method) were spread uniformly at a 1-2 cm thickness layer on wire mesh. All the samples were plastic-covered above and below to block moisture ingress during rain and at night. The samples were turned by hand once a day, at 1:00 PM for uniform drying, and dried until a constant weight was obtained. After drying, the berries were removed from spikes and sifted. The samples were milled and passed through a 0.50 mm sieve to obtain uniform fine powder. Three replicates were analyzed per treatment.

Drying duration is the time required to dry black pepper treated differently until constant weight is obtained. Drying duration and weight recordings were made each day, starting from the time the samples were delivered to the drying wire mesh bed until a constant sample weight was obtained. The sample weight was measured daily using an electronic weighing balance with a precision of 0.001 g.

The sample dry recovery (%) was computed in percentage from the sample fresh weight (W_1) measured after harvest and the sample dry weight (W_2) measured after drying using the following formula:

$$\text{Dry recovery } (\%) = 100 - \left[\frac{(W_1 - W_2)}{W_1}\right] \times 100$$

The moisture ratio (*MR*) of black pepper samples during the drying period was obtained using Equation 1.

$$MR = \frac{M_i - M_e}{M_0 - M_e} \quad (1)$$

where,

MR - dimensionless moisture ratio

M_i - product moisture content (g water/g solid) at time 't'

M_e - equilibrium moisture content (g water/ g solid)

M_0 - initial moisture content of the product (g water/ g solid)

Due to the insignificant value of M_e in comparison with M_i and M_0, it can be simplified to Equation 2 according to Goyal et al. (2007) and used for analysis.

$$MR = \frac{M_i}{M_0} \quad (2)$$

All materials other than pure black pepper berries were weighted and computed against pure black pepper as % by weight and considered as extraneous matter (Anbalagan et al., 2010).

The colors of the dried black pepper samples were determined visually according to three classifications: light black, black-brown and black.

Oleoresin content (%) was extracted using the Soxhlet apparatus accompanied with hot extraction techniques. Extraction was performed using hexane as an organic solvent. A 10 g of dried black pepper powder was placed in filter paper and then inserted in glass columns by putting non-absorbent cotton below. A 250 mL of hexane was added to a 500 mL flask and the extraction was performed for 4-5 hours at 40 ºC. Solvent removal was done by a rotary vacuum evaporator at 50 ºC and 90 RPM. Subsequently, the flask was placed in a hot air oven at 110±2 ºC until two consecutive weightings taken at 1½ hours intervals did not differ by more than 1 mg (ASTA, 2002). Finally, the flask was cooled in a desiccator and weighed and quantified as a percent weight-weight basis according to the formula described by ASTA (2002) and Daniel et al. (2008).

$$\text{Oleoresin content (\%)} = \frac{\text{weight of oil (g)}}{\text{weight of sample (g)}} \times 100 \quad (3)$$

Essential oils were obtained from the powdered black pepper by the hydro-distillation method using a Clevenger-type apparatus. A 100 g of dried powdered black pepper was placed in a 2000 mL round bottom flask, and 1000 mL of water was added to the flask. Distillation was conducted in a thermostatically controlled heating mantle set at 70 ºC for 4-5 hours for the isolation of essential oil (Sayyad & Chaudhari, 2010; ISO, 2008). After successive extraction procedures, oil was collected using a separator funnel and quantified as a volume-weight basis expressed in mL/100 g.

$$\text{Essential oil content (mL/100g)} = \frac{\text{volume of oil (mL)}}{\text{weight of sample (100g)}} \times 100 \quad (4)$$

Experimental design and analysis

The experiment consisted of eleven curing methods assigned using a completely randomized design (CRD) with three replications. The data obtained were subjected to an analysis of variance (ANOVA) and the least significant difference (LSD) was used to separate the means computed. The data were processed using the SAS software 9.2 Version.

RESULTS AND DISCUSSION

Drying duration and moisture ratio

Changes in the moisture ratio of black pepper samples relative to different drying durations are shown in Figure 2. There is a strong linear relationship between the moisture ratio of black pepper and drying time in both sun drying and shade drying processes. The moisture ratio of black pepper reduced gradually over longer periods of drying time. The sun drying of black pepper exhibited a high drying rate initially, but no constant drying rate was found in the whole drying process. The moisture loss ratio of black pepper was affected by water content, blanching and temperature interaction. The two modes of drying (open sun and shade drying) differ in drying duration (Tab. 1). Blanching berries for 2 min and sun drying (T2), and sun drying spikes for 2 days and then blanching detached berries for 10 min and sun drying (T10) required the shortest drying duration of 5 days (Fig. 2). This implies that blanching and the highest air temperature received in the open sun drying accelerates the drying of black pepper berries. In addition, the blanching of spikes for 2 min and then sun drying (T4), and direct sun-drying of berries after harvest (T6) required the second shortest drying duration of 6 days. The shorter drying duration in blanched berries may be due to the partial breakage of pepper's cell wall during blanching, which allowed for faster moisture diffusion (Wang et al., 2017; Kaymak-Ertekin, 2002). However, the direct shade drying of spikes after harvest (T9) required the longest drying duration of 13 days). Sun drying is effective in a few days, whereas more than a week is required for shade drying. Paul et al. (2021) reported that unblanched and sun-dried samples required more drying time (6 days) than blanched and mechanically dried samples. Similarly, using the sun drying method, Patil (1989) reported that a drying duration of 4-5 days is required depending on the environmental conditions. In this study, most of the sun-dried black pepper samples required an average of 6.7 days to dry, whereas shade drying required twice as much as sun drying. Pirbalouti et al. (2013) also pointed out that shade drying took longer than sun drying. This extreme delay of shade drying could also lead to mold development issues. Moreover, current results are in support of the previous report by Joy et al. (2002) and Purseglove et al. (1981), who reported that the quality improvement of black pepper and other spices is strongly positively correlated with the shortening of drying duration.

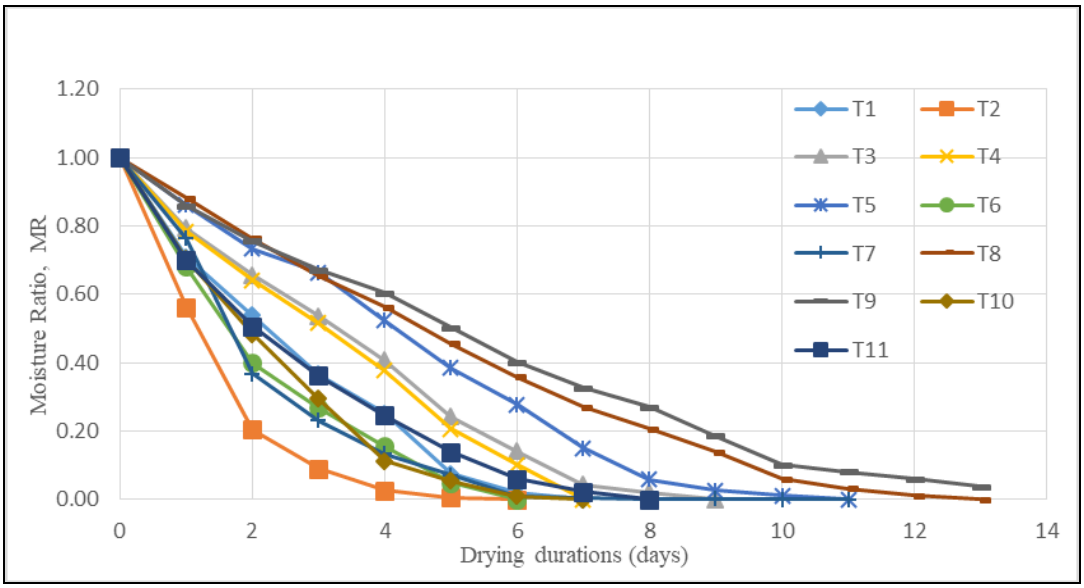


Figure 2. Moisture ratio (MR) relative to different drying durations of black pepper

Dry recovery (%) of black pepper

The curing and drying methods employed exhibited significant differences relative to the average dry recovery of black pepper samples ($p < 0.05$) (Tab. 1). The maximum dry recovery (32.63%) was recorded in the spikes blanched

for 2 minutes and shade-dried sample (T5). However, this value did not show a statistically significant difference with the values obtained for the berries blanched for 2 minutes and then shade-dried (T3), and direct shade-dried berries after harvest (T8). The minimum dry recovery (29.93%) was recorded in the berries blanched for 2 minutes and then sun-dried (Tab. 1). It was found that dry recovery was more influenced by the drying method because most of the shade-dried samples had the highest recovery percentage. The sun-dried samples had lower dry recovery than the shade-dried samples. This might be due to the fact that direct sunlight damaged the cell structure, altering the moisture content by accelerating the loss of moisture. Although the shade-dried samples exhibited higher dry recovery than the sun-dried samples, their drying process is time-consuming, unhygienic and may increase the chance of microbial infection. The moisture loss rate for the shade drying method was lower as compared to direct sun drying. This might be due to low air temperatures employed in the shade drying method, which is positively correlated to drying time. Moreover, the black pepper variety, rainfall rates, temperatures, sunlight intensity and moisture levels had a great role in determining the dry recovery of the black pepper samples (Ganapathi et al., 2018).

Table 1. Effect of blanching and drying methods on the physical characteristics of black pepper

Trt	Treatments	Drying duration (days)	Dry recovery (%)	Extraneous matter (%)	Color
T1	1-2 days heaping spikes and then sun drying berries	7	30.80^{bc}	0.77^{cd}	black brown
T2	Blanching berries for 2 min and then sun drying	5	29.93^{c}	0.46^{e}	black brown
T3	Blanching berries for 2 min and then shade drying	9	32.53^{a}	0.81^{cd}	black brown
T4	Blanching spikes for 2 min and then sun drying	6	31.36^{abc}	0.73^{cd}	black brown
T5	Blanching spikes for 2 min and then shade drying	11	32.63^{a}	1.23^{ab}	black brown
T6	Direct sun drying of berries after harvest	6	31.28^{abc}	0.65^{de}	black
T7	Direct sun drying of spikes after harvest	9	32.33^{ab}	0.76^{cd}	black
T8	Direct shade drying of berries after harvest	13	32.61^{a}	1.15^{b}	black brown
T9	Direct shade drying of spikes after harvest	14	31.48^{abc}	1.40^{a}	light black
T10	Sun drying of spikes for 2 days and then detaching berries and blanching for 10 min and sun drying	5	30.13^{c}	0.90^{c}	black brown
T11	Sun drying of spikes for 2 days and then detaching berries and blanching for 10 min and shade drying	8	31.12^{abc}	1.27^{ab}	black brown
	LSD (5%)		1.57	0.19	
	CV (%)		2.94	12.48	

Legend: TRT - treatments; The means followed by the same letters within the columns do not differ significantly at $\alpha = 0.05$.

Extraneous matter (%)

The direct shade-dried spikes after harvest (T9) had the highest extraneous matter weighted, which was significantly different ($p < 0.05$) from other treatments, except for T11 and T5 (Tab. 1). However, blanching berries for 2 minutes and then sun drying resulted in the lowest extraneous matter (0.46%). This may be due to sun drying being free from leaves and unwanted material or drops from the shade tree. In other terms, this could lead to the risk of more contamination and re-moistening of the samples before reaching the optimum moisture content. Generally, sun drying reduces extraneous matter, which might indicate that the drying period is faster. This better effect is accomplished with blanching. Similarly, IPC (2008) reported that hot water blanching reduces contaminants and increases drying rates. This finding suggests that the blanching of berries for 2 minutes, followed by sun-drying, and the direct sun drying of berries (without blanching) attained the Indian standard (<1%) for the extraneous matter. Blanching was found more favorable because it minimizes drying durations, the cost of keeping samples during drying, and to some extent limits climate-dependence. Such practice is also helpful in removing any foreign material and dust from the product. In this study, most sun-dried samples met the ASTA (1998) cleanliness specifications, Indian Standard, and Agmark standards of pepper quality. In another study, Joy et al. (2002) reported that drying influenced the quality of the spice produced.

Color

Drying methods influenced the color of black pepper samples as they turned from greenish berries or spikes to brown-black, dark brown, and black after drying. Blanching enhanced the formation of the black-brown color of black pepper regardless of the drying method (shade and sun drying). The content of greenness decreased significantly as a result of blanching, leading to a color change from green to black-brown. In addition, good blanching duration minimizes drying time and limits the effect of enzymatic browning. As compared to direct sun drying, the black-brown color of the shade-dried samples might be due to the fact that natural light promotes color degradation or fading effect, resulting in oxidation reactions. New drying techniques could be helpful in limiting

both enzymatic and non-enzymatic oxidative reactions. This study was in agreement with Gu et al. (2018), who concluded that black pepper was blacker in color and more uniform after the heat treatment (2 min 80 °C) than the direct sun drying. The blackening of pepper involves enzymatic and non-enzymatic reactions. Polyphenol oxidase (PPO) and peroxidase (POD) are the primary enzymes that cause browning and are responsible for the blackening of black pepper (Variyar et al., 1988; Weil et al., 2017). Similarly, other authors reported that blanching improves the color of black pepper (Jacob et al., 1985; Thangaselvabal et al., 2008). However, Dhas & Korikanthimath (2003) stated that blanching can deteriorate the color of black pepper, even if it was helpful to minimize the microbial load on black pepper. Through optimizing the drying function like drying temperature, time, and air velocity, the variation in color change could be reduced. Pre-treatments such as blanching and pulsed electric field were effective in improving the color of dried herbs before drying (Di Cesare et al., 2003) and (Kwao et al., 2016), respectively. In another study, Sledz et al. (2016) reported good color retention and lutein percentage from parsley herb blanched before drying.

Essential oil content

The effect of the curing and drying methods on the essential oil content of the black pepper samples showed a significant difference ($p<0.05$) between the treatments (Tab. 2). The three highest essential oil contents (2.00, 1.90, and 1.87 mL/100g) were detected in the blanched and then sun-dried samples (T2), direct sun-dried berries (T6), and heaped then sun-dried samples (T1), respectively. These results are fairly comparable to those of Jacob et al. (1985), who reported that blanching enhances the loss of essential oil if the blanching temperature is more than (80-82 °C). Therefore, before drying, blanching in hot water at 80 °C for 2 minutes minimizes the amount of oil to be lost. An increase in blanching temperature and duration may result in quality deterioration. There is no difference in essential oil contents between the shade-dried samples (T5, T8, T9, and T11) regardless of the curing method. Volatile compounds remained unstable during processing. However, in other studies, using the shade drying method was preferred for maintaining the herbs' volatile content and color as compared to hot-air drying, sun drying, microwave drying, and freeze-drying for different types of herbs such as rosemary (Khorshidi et al., 2009), basil (Hassanpouraghdam et al., 2010), mint (Rababah et al., 2015). Variations in essential oil constituents during drying were determined according to the biological elements of the herbs (fresh moisture content, plant age, growth habit, and season of harvest) (Ascrizzi et al., 2018).

Table 2. Effect of drying and curing methods on the essential oil and oleoresin contents of black pepper

Trt	Treatments description	Essential oil (mL/100g)	Oleoresin content (%)
T1	1-2 days heaping spikes and then sun drying berries	1.87^{abc}	7.85^{a}
T2	Blanching berries for 2 min and then sun drying	2.00^{a}	8.08^{a}
T3	Blanching berries for 2 min and then shade drying	1.73^{bcd}	7.31^{ab}
T4	Blanching spikes for 2 min and then sun drying	1.76^{bcd}	7.52^{ab}
T5	Blanching spikes for 2 min and shade drying	1.66^{de}	6.96^{b}
T6	Direct sun drying of berries after harvest	1.90^{ab}	8.15^{a}
T7	Direct sun drying of spikes after harvest	1.72^{cd}	7.62^{ab}
T8	Direct shade drying of berries after harvest	1.63^{de}	8.10^{a}
T9	Direct shade drying of spikes after harvest	1.53^{e}	8.05^{a}
T10	Sun drying of spikes for 2 days and then detaching berries and blanching for 10 min and sun drying	1.75^{bcd}	8.06^{a}
T11	Sun drying of spikes for 2 days and then detaching berries and blanching for 10 min and shade drying	1.67^{de}	7.99^{a}
	LSD (5%)	0.18	0.87
	CV (%)	6.00	6.61

Legend: TRT - treatments; The means followed by the same letters within the columns do not differ significantly at $\alpha = 0.05$.

Oleoresin content (%)

Curing and drying methods showed no impact on the oleoresin content of black pepper samples ($p > 0.05$), except for a slight difference in the instance of T5 (blanching spikes for 2 min and then shade drying) (a relative loss of 14.60%) (Tab. 2). The oleoresin content (ranged from 6.96% to 8.10% of dry basis) implies no significant difference between the treatments. In this study, the processing method did not affect the black pepper oleoresin content even at 10 minutes of blanching. This might be due to the outer pericarp of black pepper berries limiting the loss of oleoresin compounds. In this study, higher oleoresin contents were recorded than the minimum limit of 7.5% reported by USFDA (the United States Food and Drugs Administration standard). Shankarikutty et al. (1982) also reported the origin of spice as a major factor determining the oleoresin content.

CONCLUSION

Processing had a significant role in black pepper color, essential oil content, and drying duration. Blanching berries for 2 minutes followed by sun drying and direct sun drying of berries after harvest resulted in higher essential oil contents, oleoresin contents, shorter drying duration, and enhanced color of the products. Berries should be separated from spikes before drying. Prospective studies on the separation of phenolic compounds for reducing the microbial load under different drying conditions should be conducted in the future.

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Conflict of interest: The authors declare that they have no conflict of interest.

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