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Evaluation of solar dryers on drying and sensory properties of salted Tilapia filets, Tigray, Northern Ethiopia

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Solar dryers are used to preserve very perishable foods like fish for long period of time by lowering the moisture content in high temperature areas and contribute to fish postharvest loss reduction. Therefore this study was conducted to evaluate dryers on moisture loss, moisture contents, drying and sensory properties of salted tilapia fillets. The experiment consisted of a factorial design, two factors with two levels of treatment processes, that is dryers (raised rack tent, solar tent and family tent) and salting methods (dry salted and brined). Open air dryer was used as control. Results show that there was no significant ($p>0.05$) difference in minimum temperature record between raised rack and solar tents but significantly ($p<0.05$) different in maximum temperature values among dryers. The highest temperature record was observed in raised rack tent (50°C) while lowest was in open air (26°C). Dryers and salting methods had significant ($p<0.05$) effect on moisture loss, moisture content (oven dried) and sensory properties. Brined fish fillets dried in open air showed highest moisture loss (79.54%) followed by raised rack tent (79.39%). Significant lowest moisture content values were observed in the products dried in raised rack tent (10.17%) using dry salted method than other dryers. Sensory evaluation revealed that the most acceptable product was obtained from brining method dried in raised rack tent. The color, flavor, texture, taste and overall acceptability scores of this product were 4.60, 4.20, 4.37, 4.40 and 4.47 (5-point hedonic scale), respectively. Therefore, raised rack tent fish dryer technology was found to produce acceptable sensory dried products and need to be demonstrated and popularized in high temperature areas.

Key words: Dryers, moisture content, moisture loss, salting method and sensory properties.

INTRODUCTION

Fish is a highly nutritious food and particularly valued for its high quality protein when compared to those of meat and egg (Ojutiku et al., 2009). Fish is known to be a source of protein rich in essential amino acids (lysine, methionine, cystine, threonine, and tryptophan) (Sikorski, 1994), micro- and macroelements (calcium, phosphorus, fluorine, iodine), fats that are valuable sources of energy, fat-soluble vitamins, and unsaturated fatty acids that, amongst other benefits, have a hypocholesterolemic effect (antiarteriosclerosis) (Ismail, 2005). Fish and its residue are an easily digestible source of high biological value protein, essential fatty acids, and minerals as well as vitamins A, D, and B complex, all of which make for a product of high nutritional value (Kristinsson and Rasco, 2000).

Fish is currently being used as a good tool for food therapy and source of therapeutic substances for the treatment of coronary diseases, auto-immune diseases, anemia and protein energy malnutrition (Glomset, 1986). However, fish is highly perishable because it provides favorable medium for the growth of microorganisms after death (Ojutiku et al., 2009; Aliya et al., 2012; Oparaku and Mgbenka, 2012).

Drying or dehydration is used to describe any process involving the removal of water from fish or fish product by evaporation (Eyo, 2001). Sun drying is fraught with problems such as contamination by dust and insect infestation because the fishes are dried on mats spread on bare ground that leads to spoilage (BOSTID, 1988). Dried fish are usually considered shelf stable, therefore, often stored and distributed unrefrigerated and the resulting product is easily transported to market or from one place to another. The characteristic of dried fish that makes them shelf stable is their low water activity (aw) and thus prevention of growth of many spoilage microorganisms (Antonios et al., 2005; Rorvik 2000). Fish with moisture loss of between 66 and 75% may not be infected by microbes and the shelf-life of the fish could be increased in solar dryers (Clucas, 1982; Frazier and Westhoff, 1998).

To arrest these problems, many designs of solar dryers have been developed for the preservation of fish. Solar dryers employ some means of collecting or concentrating solar radiation with the result that elevated temperatures and, in turn, lower relative humidity is achieved for drying (Oyero et al., 2007). Along with the evaluation of the effectiveness, efficiency, and performance of the low-cost solar driers in terms of moisture reduction, it is also desirable to analyze the organoleptic characteristics of the final dried products coming from the low-cost solar driers. This is usually done by means of human senses or organs to test for some properties on the dry product. Rahman et al. (2012) used appearance, flavor, texture, filthiness, scales, wetness, and saltiness as organoleptic characteristics of dried fish products. Several studies have been done on the organoleptic characteristics of various fish species dried by different methods. For example, Longwe and Kapute (2016) studied nutritional,microbial and sensory quality of solar tent dried (Samva Nyengo) and open sun dried *Copadichromis virginalis*. Ojutiku et al. (2009) did comparative study of sun drying and solar tent drying of *Hyperopisus bebe occidentalis*, and Abraha et al. (2017) also studied comparative study on quality of dried Anchovy (*Stelophorus heterolobus*) using open sun rack and solar tent drying methods.

A large percentage of the fish caught in the developing countries are lost through poor handling (Oladele and Odedeji, 2008). In Tekeze reservoir, Tigray region, there is fish production and marketing activities and the most economically important fish species are Nile tilapia, cat fish and barbus respectively. However, about 32-35% fish fillet is used for consumption and market but the remaining percentage and underutilized fish species (barbus fish species) is lost during high production season and market problems that leads to postharvest loss, environmental pollutions, human health impacts, dam water pollution and economic loss (Zebib and Tsegay, 2015). Tesfay and Teferi (2017) studied assessment of fish postharvest losses in Tekeze dam and Lake Hashenge fishery associations in Tigray region, Ethiopia and reported that preservation technology such as drying, smoking and lesser salting methods should be introduced in the area to address postharvest loss since there is lack of awareness on utilization of preserved fish products. Therefore to address these postharvest losses, evaluation and selection of low cost preservation technologies is important. In this study, moisture loss, moisture content, and sensory properties of dry salted Tilapia fillets were investigated.

MATERIALS AND METHODS

Study area

The construction of solar dryers, evaluation of drying and sensory properties of dried products was done in Abegelle Agricultural Research Center (Arequa site), Tigray, Ethiopia.

Sample preparation

A total of 30 fresh Tilapia fish (300-400 g market weight) were collected within 2 h from Tekeze reservoir, Tigray and transported in an ice box to Arequa farm. Tilapia fish were washed thoroughly with clean water, scaled, gutted and eviscerated. Then, the fillets (507-550 g weight) were used in each dryer.

Construction of dryers

Solar tent dryer

This was prepared with a size of 2 m height and 1.7 m length frame

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Figure 1. Solar tent dryer.

wooden poles completely covered with strong transparent plastic sheet to protect from direct sun light, dusts, and flies and to dry the product quickly since the plastic heats quickly when under direct sunlight. Dryer rack (30 cm height x 1.4 m length and 0.6 m width) was made using rectangular wooden poles covered by galvanized mesh wire (16 cm^2 holes) upon which fish fillets spreads (Figure 1).

Raised rack tent dryer

This was constructed with size of 1 m height, 1 m length and 1 m width frame wooden poles covered by strong transparent plastic sheet. Dryer rack (95 cm width x 95 cm length) was made using rectangular frame covered by galvanized mesh wire upon which fish fillets spreads (Figure 2).

Family tent dryer

This was prepared with a size of 2 m height and 1.5 m length triangle frame wooden poles completely covered with strong transparent plastic sheet. Dryer rack (60 cm width x 1.4 m length) was made using rectangular frame covered by galvanized mesh wire upon which fish fillets spreads (Figure 3).

Open air dryer

This was prepared with dimensions of 50 cm height, 1 m length and 60 cm width frame wooden poles covered by galvanized mesh wire upon which fish fillets spreads (Figure 4).

Salting methods

Dry salting

Tilapia fish fillets were well dressed with 30% (W/W) normal salt (mixture of course and powder) and then were spread in the dryers.

Brining

The fish fillets were soaked in normal salt solution (60 g salt/1L water) for 20 min. Then, it was drained for about 15 min and the fillets were spread in the dryers.

Figure 2. Raised rack tent dryer.

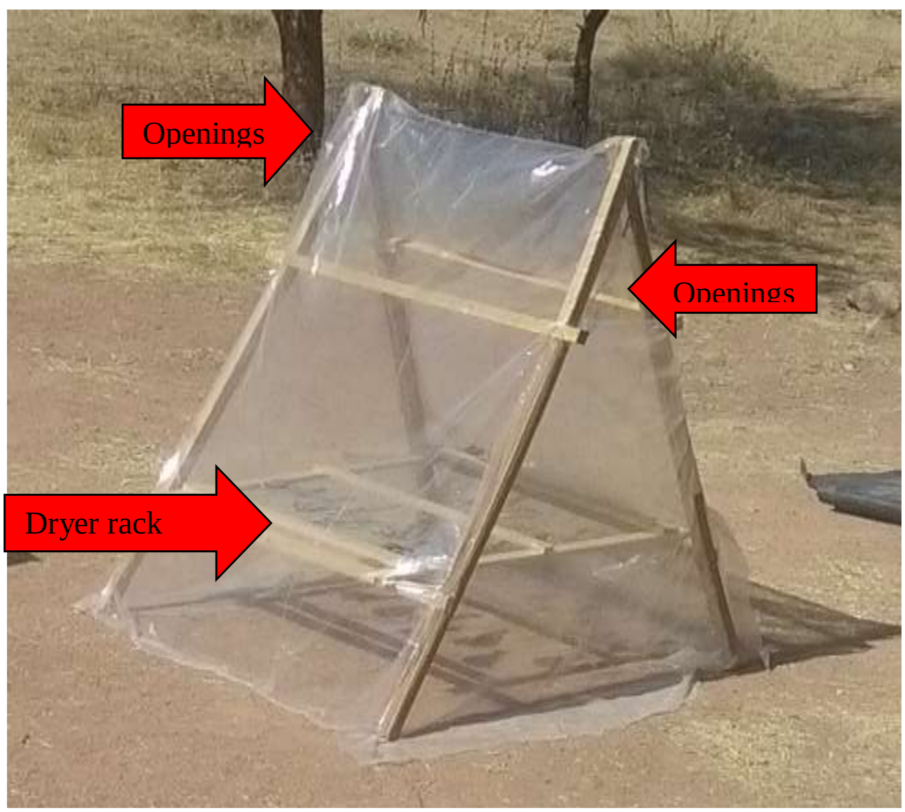

Figure 3. Family tent dryer.

Figure 4. Open air dryer.

Drying procedure

Tilapia fish fillets were weighed using digital sensitive balance (capacity: 5000 g x 0.1 g). The weighed fillets were spread in the dryer rack in 4 cm spacing between fillets to minimize load and enhance drying days and turned over every 2 h hygienically in each dryer to ensure uniform drying. The fillets were dried from 8:30 am-4:30 pm since the area is shiny in these time intervals. Then, weighed fillet in the dryers were collected at 4:30 pm and packed in polyethylene to protect moisture absorption in each drying day.

Experimental design and treatments

A 3^2-factorial design with two independent variables at three treatments was applied. The independent variables were: salting methods (dry salting and brining) and dryers (solar tent, raised rack tent and family tent).

Inside air temperature record

The inside temperature was measured at 9:00 am, 12:00 am and 3:00 pm time intervals by putting temperature sensor inside the dryer until a relatively much stable reading were obtained.

Moisture loss and moisture content

Moisture loss determination

The initial and continuous weight of fillet was weighed in each drying day and the final weight of fillets was recorded until stable moisture loss was obtained during drying days. Moisture loss of fish fillets during drying days were calculated by using the following formula:

$$MC = \left(\frac{IW - FW}{IW} \right) \times 100$$

Where, MC = Moisture loss of the sample (%); IW = Initial weight (g); FW = Final weight (g).

Moisture content determination

Moisture content of the sample was determined according to AOAC (1995). Clean and dry dish was prepared and the mass was weighed as W_1. The representative sample (about 3.0 g) was weighed (W_2) (mass of sample + mass of dish before drying). The sample was dried at 105°C for 12 h in an oven and cooled to room temperature in a desiccator. The mass of dried sample and dish was weighed (W_3). The moisture content of sample was calculated by using the following formula:

$$MC = \left(\frac{W_2 - W_3}{W_2 - W_1} \right) \times 100$$

Where, MC = Moisture content of sample (%); W_1 = mass of dish (g); W_2 = mass of sample and dish before drying (g); W_3 = mass of sample and dish after drying (g).

Sensory evaluation

Sensory evaluations of dry salted fish fillet products were carried

Table 1. Inside temperature record in the dryers.

Dryer	Mean minimum temperature (°C)	Mean maximum temperature (°C)
Raised Rack Tent	32.50±0.57[a]	50.00±0.81[a]
Solar Tent	31.50±0.57[a]	48.00±0.81[b]
Family Tent	30.00±0.81[b]	42.50±0.57[c]
Open Air	26.00±0.81[c]	38.50±1.29[d]
CV (%)	2.35	2.04

All values are Mean ± SD of triplicate analyses, Mean ± SD in a column with the same letter are not significantly different (p<0.05).

Table 2. Moisture loss and moisture content of salted Tilapia fillets.

Product	IW (g)	FW (g)	Moisture loss (%)	Moisture content (%)
RRDS	521.40	131.60	74.76	10.17±0.11[a]
RRB	504.70	104.00	79.39	12.00±0.09[d]
STDS	525.00	133.40	74.59	10.27±0.14[a]
STB	544.60	115.80	78.74	12.09±0.29[d]
FTDS	550.00	149.30	72.85	10.57±0.11[b]
FTB	507.00	111.30	78.05	12.30±0.09[e]
OADS (Control)	517.00	109.80	78.76	11.12±1.11[c]
OAB (Control)	518.00	106.0.0	79.54	12.32±0.12[e]

MC values are mean ± SD of duplicate analyses. Mean ± SD in a column with the same letter are not significantly different (p<0.05). IW= initial weight; FW= final weight; RR=raised rack tent; ST=solar tent; FT=family tent; OA=open Air; DS=dry salted; B= brined.

out by 10 panelists from staff who are familiar with the product. Sensory attributes were evaluated using acceptability test (David and Francis, 1957). The acceptability test (color, flavor, taste and overall acceptability) were evaluated using five point hedonic scale rated from 1 (extremely dislike), 3 (neither like nor dislike) to 5 (extremely like). The more widely used practice of three digit code was used for identification of samples. Product samples were arranged in random order on white plates and served to the sensory judges. Orientation was given to the judges on the procedure of sensory evaluation before the test session.

Statistical analysis

The two way analysis of variance (ANOVA) were used to test for significant variations between means of salting methods and drying technologies using appropriate software (SAS institute and Cary, NC) version 9.0. Duncan's multiple range tests was used to identify significant differences. Significance was accepted at $p < 0.05$.

RESULTS AND DISCUSSION

Inside temperature record in the dryers are shown in Table 1. There was no significant difference in mean minimum temperature record between raised rack tent (32.5°C) and solar tent (31.5°C) (p>0.05). All treatment dryers had higher temperature record than open air dryer. However, significance differences in mean maximum temperature were found (p<0.05). The highest (50°C) maximum temperature was recorded in raised rack tent dryer but lowest was for open air dryer (38.5°C). Mustapha et al. (2014) reported mean maximum inside temperature range (38.00 -50.00°C) and minimum temperatures range (20.00-22.00°C) was recorded in the solar and open-sun dryers respectively which is similar with current study results in maximum temperature but lower in minimum temperature values. This may be due to environment air movement and sun radiation differences in the area.

Table 2 shows moisture content and moisture loss of the dried salted tilapia meat products. The highest moisture loss and moisture content was observed in the control (open air dryer) while least moisture loss was in family tent dryer in both salting methods. Sulieman and Sidahmed (2012) reported lower the moisture loss values in open air (69.00%) and solar dryers (70.00%) than the current study results. Mustapha et al. (2014) also reported 69.56% moisture loss values in open air dryer

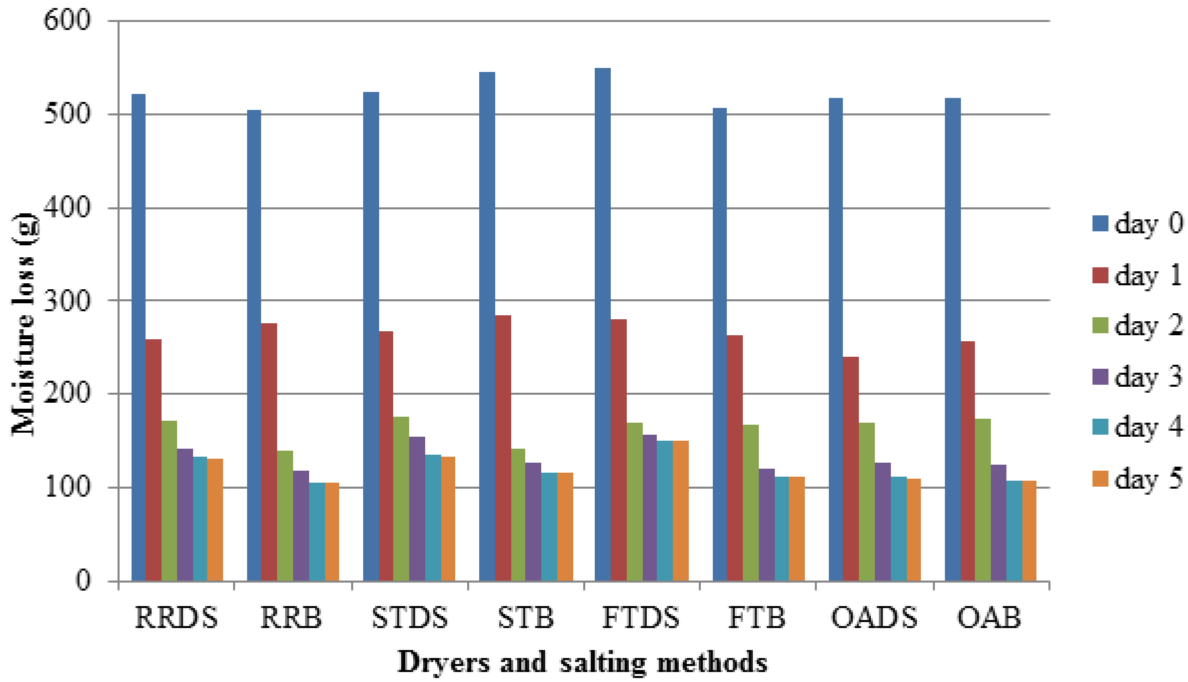

Figure 5. Moisture loss variation with dryers and salting methods during drying days.

and 74.57% in solar dryer.

The highest moisture content was observed in the control (open air dryer) in both salting methods while least was in family tent (12.30%) and the control (12.32%) in brined product with no significant ($p>0.05$) differences between them. The moisture content values (10.84 and 11.20%) in open air and solar dryers respectively were reported by Mustapha et al. (2014) which were similar finding to current study results but lower moisture content values (5.95 and 5.05%) was reported by Sulieman and Sidahmed (2012) in open air and solar dryers respectively. Sablani et al. (2003) also reported moisture content values of processed fish sardines (16.65, 10.10 and 18.09%) dried in open rack, conventional cabinet and multi rack dome (top and bottom rack) solar dyer respectively which are higher values in open rack and multi rack dome dryer than current result values but similar finding in conventional cabinet dryer. Lower moisture content values (9.00 and 7.90%) were found in anchovy (*Stelophorus heterolobus*) dried in open rack drier and solar tent drier respectively (Abraha et al., 2017) when compared with current study results. Longwe and Kapute (2016) reported moisture content values in sun dried *Tilapia rendalli* (7.67%) and *Oreochromis karongae* (8.33%) which are lower than the finding reported by Abraha et al. (2017) and current finding values. Figure 5 show moisture loss during five drying day. As the drying days increased, moisture loss increased. During day 1 drying, 50.4 and 49.72% moisture was lost in dry salted and brined fillets respectively.

The results of sensory acceptability test of dry salted products are presented in Table 3. The dryers and salting methods revealed significant differences in color, flavor, taste, texture and overall acceptance scores of products ($p<0.05$). Panelist's preferred brined fish dried in raised rack tent. Color acceptance scores of RRB were the highest (4.60) and significantly different ($p<0.05$) from other dried products in the dryers and the control. The lowest value (2.40) was scored in dry salted fillets dried in the control (OADS). Open air dried products were less acceptable than other dryers in both salted methods since the fish were exposed to dust and direct sun light resulted in off color change that contributes poor color acceptance. Chavan et al. (2011) reported that the mackerel fish dried in the open sun showed whitish yellow patches on the surface but a bright attractive color when dried in the solar tunnel drier. All the scores (between 3.60 and 4.60 in a scale of 5) were moderately accepted by panelists in all plastic covered solar driers.

The highest value of flavor (4.20) was recorded in RRB and lowest (2.40) was recorded in OAB. Products dried in the control showed lower flavors acceptability than other dryers; this may be due to oxidation reaction of fatty acids with direct sunlight that contributes off flavor in the product. Chavan et al. (2011) reported that the mackerel

Table 3. Sensory acceptability of salted Tilapia fillets.

Product	Color	Flavor	Texture	Taste	Overall Acceptability
RRDS	4.20±0.45[a]	3.80±0.45[d]	4.40±0.35[c]	4.30±0.25[f]	4.40±0.35[e]
RRB	4.60±0.55[b]	4.20±0.45[c]	4.37±0.55[c]	4.40±0.55[d]	4.47±0.55[f]
STDS	4.00±0.01[c]	3.40 ±0.55[e]	4.40±0.55[c]	4.00±0.50[c]	4.00±0.01[d]
STB	4.20±0.05[a]	3.60±0.50[f]	4.20±0.45[d]	4.20±0.01[e]	4.00±0.02[d]
FTDS	3.80±0.45[d]	3.38±0.55[e]	4.00±0.71[a]	4.00±0.02[c]	4.20±0.45[c]
FTB	3.60±0.55[e]	3.60±0.56[f]	4.20±0.45[d]	3.80±0.45[c]	3.60±0.55[b]
OADS	2.40±0.55[f]	2.60±0.55[a]	2.80±0.45[b]	2.40±0.55[b]	2.75±0.56[a]
OAB	2.60±0.55[g]	2.40±0.55[b]	3.00±0.00[e]	2.00±0.00[a]	2.80±0.45[a]
CV (%)	12.90	11.53	12.73	10.22	11.47

All values are Mean ± SD of ten analyses. Mean ± SD in a column with the same letter are not significantly different ($p<0.05$). RR=Raised Rack tent; ST=solar tent; FT=family tent; OA=open air; DS=dry salted; B= brined.

fish dried in the open sun showed fishy odor but good odor dried in the solar tunnel drier. Abraha et al. (2017) found higher odor score values in solar tent dryer (7.11) than open rack dryer (6.77).

OADS and OAB showed significantly ($p<0.05$) lower scores of texture (2.80 and 3.00 respectively) than in the other dryers. The highest texture (4.40, 4.40 and 4.37) were recorded in STDS, RRDS and RRB respectively. Slightly higher texture score of dried anchovy fish (7.22 and 7.11) was gotten in open rack dryer than solar tent dryer respectively which is in contrary with current score values. The texture evaluation scores of all products were above 4 on the 5 point scale showing the acceptability of the products. All driers showed higher scores of taste than the control. The highest (4.40) taste score was found in RRB while lowest (3.8) was in FTB.

The dryers and salting methods revealed significant ($p<0.05$) differences in overall acceptance scores of products. The overall acceptability of the RRB and RRDS (4.47 and 4.40) score was significantly ($p<0.05$) higher than the other driers and control dried products, respectively. It can be seen that panelist’s preferred brined fish dried in raised rack tent but the control resulted into lowest overall acceptability (2.75 and 2.80) in OADS and OAB respectively. Results show that all the scores obtained in the overall acceptability that varied between 4.00 and 4.47 indicated that all the products were in the range of “like moderately” and like extremely”. Open air products were less acceptable than other dryers in both salted methods. Since the fish were exposed to dust, direct sun light, invasion and infestation by flies resulted in poor sensory quality. This observation agrees with the sensory evaluation done on fish dried with low cost solar dryers by Sengar et al. (2009) and Rahman et al. (2012). Asmare et al. (2016) found acceptable sensory quality in barbus (*Labeo barbus intermedius*) fish fillets dried in solar tent dryer. Sulieman and Sidahmed (2012) also reported higher acceptable sensory quality in solar plastic sheet dryer than rabbit wire and open air dryers.

CONCLUSION AND RECOMMENDATIONS

Open air dryer showed higher moisture loss in salted tilapia fillet product than other dryers. Sensory evaluation revealed that the most acceptable product was obtained from brined product dried in raised rack tent dryer that produces good moisture loss and content during five drying days than other dryers. Therefore raised rack tent dryer should be demonstrated and popularized in high temperature areas.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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