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Improving food security in Iran: quantifying post-harvest rice losses

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ABSTRACT

Purpose: Food is a basic need for human life. Ensuring food security requires guaranteeing adequate food availability, accessibility, and utilization along with the sustainability of the food system. Food availability can be improved by decreasing food losses. The goal of this study is to document the causes and quantify the amount of losses in Iran's rice supply chain. **Research method:** A cross-sectional survey method was used to collect data through interviews with some actors of the rice production chain operating in Mazandaran province, Qaemshahr, in 2015, to approximate percentage weight losses at the different stages in the supply chain. **Main findings:** The rice losses are estimated to be about one-third of the production that could feed 18 million people per year. On the other hand, the rice losses imply an economic loss of 1,403 million U.S. dollars, annually, and losing some scare resources, such as water, in Iran. **Limitations:** It is not easy to apply the ways to collect the useful and more accurate data in order to find the most important reasons of food losses for each stage and process of the food supply chains. **Originality/Value:** It was found that it is necessary to invest in the marketing systems, renew the supply chain and improve knowledge of the actors of the rice chain -from producing to consuming- in Iran's rice system to reduce the physical and economical estimated losses of rice.

INTRODUCTION

Food is a necessity for human life. With a rising population, which is estimated to overtake more than 9 billion by 2050, and a predictable increase in food demand, guaranteeing enough food to feed the world can become an even harder challenge (Dou et al., 2016). According to the World Food Summit, the definition of food security is when all people at all times have physical, social and economic access to sufficient and safe food (World Food Summit, 1996). The issue of food losses overlaps with the issue of food security as it affects the sustainability and resilience of food systems (Ardakani et al., 2019) and their ability to ensure food security (HLPE, 2014). On the other hand, by losing food, all of the resources spent during the supply chains are also missed (Thyberg & Tonjes, 2016). Therefore, reducing food losses across the entire food chain will improve food availability (Godfray et al., 2010; Pearson et al., 2013; Buzby et al., 2014) and will be an important part of any strategy to feed the growing population in the world (Foresight, 2011).

Food losses imply a deduction of the potential quantity of food that might be produced and distributed along the supply chains, from farm to table (Conteh et al., 2015; Routroy & Behera, 2017). The food supply chain is a system of organizations, people, and activities involved in moving food from the producer to the consumer (Beretta et al., 2013) and that losing food is a result of an ineffective operation of these drivers of the supply chain (Abass et al., 2014). Researchers, along with other actors such as farmers, governments and non-governmental organizations, and extension officers might play an important role in tackling the issue of food losses (Abass et al., 2014; Bolarin & Bosa, 2015). Decreasing food losses is considered one of the most favorable measures to improve food security and positively affect the use of resources, such as water (Kummu et al., 2012) to be secured (Alonso-Amelot & Avila-Núñez, 2011).

Despite the many technical growths in production and post-production stages since the 1970s when food losses were first measured by FAO, the problem is still significant and differs in the crops and countries (Kader et al., 2012). The existing studies on food losses have focused on post-production losses (Abass et al., 2014; Bolarin & Bosa, 2015). These studies have played a crucial role in defining the entity of this phenomenon, its causes, and possible solutions. However, further insights might emerge if new contexts and food sectors are explored. According to some studies, food losses are mainly caused by a malfunction in the processing, packaging, and storing of food. The malfunction is due to a combination of inefficient and backward procedures and scarcity of knowledge among food chain actors (FAO, 2013). Inefficiencies in the upstream of the food chains affect more developing countries than developed ones (Pirmoradi et al., 2013).

One-third of food made for human consumption in the world is lost, amounting to 1.3 billion tons annually (Dou et al., 2016). The World Bank estimates that there are between 12 and 16 million tons of post-production grains that are losses worldwide every year. This amount would be enough to feed between 70 million to 100 million people, with a yearly average consumption of 15 kg of grains per person (Basappa et al., 2007). Given the magnitude of the phenomenon, the issue of reducing global food losses has recently received increasing consideration. The FAO and other partner organizations started a global campaign on reducing food losses. The campaign targets all actors along the food chains and provides information on existing initiatives around the world (FAO, 2013). Many studies have highlighted the magnitude of the problem and identified specific targets for reducing food losses as well as policies to meet the targets (HLPE, 2014).

Rice is one of the most important food crops in the world and the basis of the diet (Guenha et al., 2014) especially for the population in Asia where approximately 90 percent of the rice of the world is produced and consumed (Sita Devi & Ponnarasi, 2009; AghaAlikhani et al., 2013). Rice, similar to other agricultural products, has a high proportion of losses that can occur during the various stages of its supply chain (Guisse, 2010; Kazemi et al., 2015). In Iran, Rice production is one of the main food chains with a production of 2,436 thousand tons annually, on average, after wheat, barley and corn. This study seeks to highlight the main figures, challenges, and solutions for the reduction of losses in the rice sector of Iran. In particular, the study focuses on the stages of the rice chain from farming to retailing because this is where most of the losses occur. Moreover, without the presumption of generalization, the results of this study might be relevant to other developing countries being major rice producers and dealing with reducing food losses in this sector.

To this end, this study will measure the scale of rice losses in Iran across the whole food supply chain (Rutten & Kavallari, 2016) and contribute determining the issues involved in food losses in the rice sector. We will do this by investigating the amount of rice lost, and the reasons for it from farming to retailing. The goal of this study is to document the causes and quantify the amount of losses in Iran's rice supply chain. Understanding where and how much rice is lost and the worth of these losses is important evidence that policy-makers can use to reduce rice losses and increase the efficiency of the farm-to-table rice supply chain to feed the growing human population.

The paper is structured as follow. Next section will present the study area, the available data as well as the methods. In section 3, we present and discuss our results. The final section will conclude the study.

MATERIALS AND METHODS

Data and study area

Rice is the second most vital food, after wheat, for the nutrition of much of the population in Iran where per capita consumption of rice is around 40 kg in a year. The latest available figures show that more than 600 thousand hectares area under rice production in Iran. However, more than 80 percent of the land farmed with rice is located in the three Northern provinces. Of this land, 265 thousand hectares are located in Mazandaran and Golestan provinces, while 230 thousand hectares are in Gilan province.

For the present study, a cross-sectional survey method was used to collect data through interviews (Beretta et al., 2013; Kitinoja et al., 2019) with some actors of the rice production chain operating in Mazandaran province, Qaemshahr City in 2015 (Fig. 1). A multistage simple random sampling technique has been used to select the respondents, which included 100 farmers, 20 processors, 20 wholesalers and 20 retailers. According to the data collected, 90 percent of the respondents are males that on an average were around 54 years of age with the most of no (or primary) education. They were asked about the amount of rice losses that they can estimate and experience in each process: harvesting, threshing, drying, milling, winnowing, and packaging, storing and transporting.

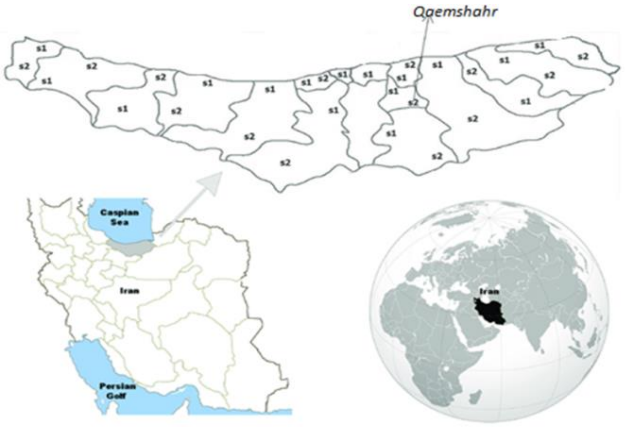

Fig. 1. Study area: Qaemshahr, Mazandaran province, Iran

Table 1. Basic mathematics equations to connect to food security and economic losses

	Item	Basic mathematics equations
1	Consumption quantity	(Production + Import) – Export
2	Losses quantity	Production × Percentage of losses
3	Value of rice lost	Losses quantity × Producer price
4	The value assigned to import the quantity of rice lost	Import quantity × Import price
5	Total missed value	(3) + (4)
6	Number of people can feed with the lost rice	Losses quantity / Consumption per capita

Post-harvest losses calculation

According to Harris and Lindblad (1978), there are several assessment methods available to measure food losses but it is difficult to find which method reveals the actual losses closer and more reliably (Alonso-Amelot & Avila-Núñez, 2011). One method is measuring real losses by following a particular food product from production to consumption, through measuring weight (or quality) losses at each stage. This approach, while difficult for some products, delivers a better estimate of food losses (Harris & Lindblad, 1978). This is mostly the focus on post-harvest losses estimation to date (Alonso-Amelot & Avila-Núñez, 2011; Abass et al., 2014). Another method of measuring food losses is to use estimates by persons who experience food losses, using a defined questionnaire. This method is somewhat easy to apply, but it can only approximate the estimated food losses (Amentae, 2016).

According to the existing possibilities for collecting the data, the method of estimating food losses by persons who experience food losses (Amentae, 2016) was employed in this study. Rice losses were estimated by relying on the traditional knowledge of the respondents (Babarabie et al., 2019) to recall the extent and relative losses happening at each stage of post-harvest handling (Teshome et al., 1999; Abass et al., 2014). They were aimed at gathering data on the losses at different stages of the studied rice supply chain. Comparisons can provide quantitative information to estimate the quantity of rice lost along the supply chain by calculating the percentage (Beretta et al., 2013) of rice lost in each stage of the supply chain and per each process.

In the present study, rice lost is calculated as the difference between the amounts (initial weights) of rice reaching (i.e., input) to a certain process (harvesting, threshing, drying, milling, winnowing, and packaging, storing and transporting) minus the amount (final weights) of rice leaving (i.e., output) the same process by interview of the actors to estimate

the amount of losses in the processes. While the percentage of the rice lost is given by dividing the amount of rice lost by the amount (initial weights) reaching the process as input (Reed, 1987; Guenha et al., 2014) in formula 1.

$$\text{Percentage Weight Losses} = \{(\text{Initial Weight} - \text{Final Weight}) / \text{Initial Weight}\} * 100 \quad (1)$$

The data collected were exposed to statistical analysis including tabular and graphical presentation techniques (Hollingsworth et al., 2006).

Food security and economic losses assessment

In addition, the study seeks to broaden its findings by estimating the quantity of rice losses and their economic value (Kitinoja et al., 2019) beyond the studied case. Basic mathematic equations are used to combine the data gathered about the losses of rice in some rice chains located in Iran using the latest available figures retrieved from the FAO website for the total production, imports and exports, producer prices, and per capita consumption of rice in Iran. Table 1 report the basic mathematics equation used in the current study.

RESULTS AND DISCUSSION

An important component in the food systems to be more efficient is the reduction of food losses across the entire food supply chains (Abass et al., 2014; Affognon et al., 2015; López-Castillo et al., 2018). Furthermore, economically avoidable food losses are of high importance in the efforts to combat hunger and to improve food security, not only in developing but also in developed countries. The analysis in this study covers the entire food supply chain that is associated with rice consumption, to recognize the causes and quantify the amounts of rice losses over all stages from harvesting to intake.

Figure 2 summarizes the percentage of rice lost per each process in the different stages of the rice chain. These stages include farming, processing, wholesaling and retailing. For each stage, there are different processes. Farming includes harvesting, threshing, drying, storing and transporting. Milling, winnowing, packaging, storing and transporting are processes of the processing stage. In the wholesaling stage, there exists winnowing, storing and transporting processes; there are storing and transporting processes in the retailing stage also.

As for the farming stage, around 5 percent of losses happen during the threshing, close to 3 percent occurs in the drying process and around 1.5 percent happens during the harvesting. This data shows that threshing, drying, and harvesting are the main causes of rice losses in the farming stage while storing and transporting in the farming stage show a very small percentage of losses as shown in Figure 2. During harvesting and drying of rice, to compare, Calverley (1996) estimated about 7 percent losses in Madagascar, 4.3 percent losses in China and 4 percent for several Asian countries. Losses for rice in threshing were 6.5 percent and 6 percent in Madagascar and Ethiopia; respectively (Abass et al., 2014).

Moving to the processing stage, see Figure 2, most of the losses take place during milling with a share of more than 10 percent. During winnowing, losses are close to 4.5 percent of total losses. The losses of rice during the storing, packaging and transporting processes represent respectively around 1.01, 0.51, and 0.01 percent of the total losses in the processing stage. From this data, it can be derived that milling and winnowing are the most ineffective processes with respect to losses in the processing stage of the rice chain. Losses for rice in Madagascar and Ethiopia were 2.5 percent; respectively and 5 percent in winnowing (Abass et al., 2014).

If we look at the wholesaling stage (Figure 2), most of the losses happen during winnowing. They amount to 3.23 percent while losses during storing and transporting amount to the 0.02 and 0.01 percent, respectively. Consequently, rice winnowing is the most inefficient process in the wholesaling stage of the rice chain with respect to product losses. Finally, in the retailing stage, 0.01 percent of rice losses derive from storing, and 0.01 percent is due to the transporting processes.

Table 2 reports the results of the estimated quantitative post-harvest rice losses (calculated through formula 1) in the different phases of the supply chain as the sum of the percentages of rice lost in the processes that constitute each stage shown in Figure 2. As Table 2 shows, around one-third (29 percent) of rice production is lost going from fields to forks. It can be compared to post-harvest losses in Africa which are frequently estimated to be between 20 and 40 percent (World Bank et al., 2011). Also, this agrees with the range of 20 percent to 30 percent losses by weight; estimated for grains by Tefera et al. (2011). Most of the losses occur in the processing stage, which equals 16.39 percent of the products that reach this stage. At the stages of farming, around 9.48 percent of rice is lost. In the wholesaling and retailing stages, respectively, around 3.26 and 0.02 percent of rice that reaches these stages are lost. Another study in Iran, Amol city, by Salmani et al. (2013) agrees with these results as the rice losses have been estimated 33 percent with a most share of processing and farming, respectively. In Tanzania, another developing country, quantitative post-harvest losses occur in the field with a share of 15 percent and during processing with a share of between 13 percent and 20 percent (Abass et al., 2014).

Figure 3 reports the total amount of rice losses in the different processes of the supply chain, regardless of the stage. These amounts result from summing up the percentages of rice lost in the same process over the different stages of the supply chain. The main contribution to rice losses happens in the milling and winnowing processes, by a share of 10.43 and 7.69 percent of the total losses. According to the respondents participated in the interviews, traditional methods and old-fashioned machinery used in the milling and winnowing actions of rice in Iran might be behind the high percentage of losses. Also, zinc deficiency and high air temperature at harvest time can increase the rice losses in the milling process.

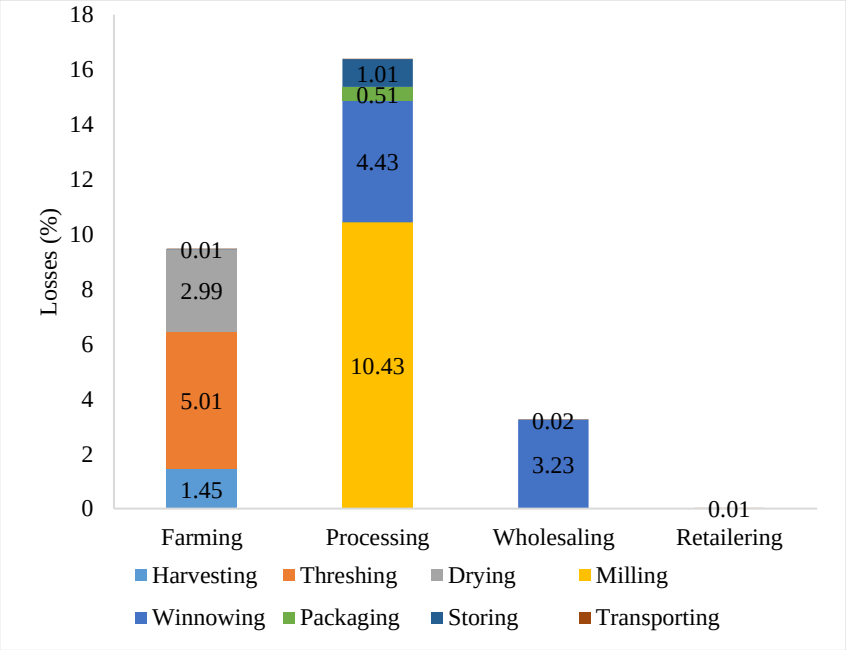

Fig. 2. Percentage of rice lost per each process in the different stages of the chain

Table 2. Percentage of rice lost at the different stages of the supply chain

Stages	Rice losses (%)
Farming	9.48
Processing	16.39
Wholesaling	3.26
Retailing	0.02
Total	29.15

The second-largest contribution to rice losses is relative to the threshing that follows with 5.01 percent of losses. The threshing is implemented during the farming stage only. Hence, all the losses due to threshing are imputable to this phase. The main reason for the rice losses during threshing is the use of combines that are not suitable for rice threshing. It is common to see farmers using combines that are meant for the threshing of other kinds of grains or rice varieties, which are different from the ones that are threshed. The farmers participated in the interviews have the same interpretation.

Drying and harvesting are the third and fourth most inefficient processes if we look at the rice losses they generate. They are also processed typically of the farming stage only and show shares of 2.99 and 1.45 percent of rice losses respectively. Based on the interviews, drying is done following both traditional practices and using modern machines. When implemented in the traditional way, losses of rice are mainly due to the action of birds and insects that eat the rice grains. When modern machines are used for drying rice, losses are due to their misuse. It is common to witness mistakes in the setting of appropriate timing, temperature, capacity, and humidity. As far as it concerns the causes of losses during harvesting, similar to threshing, there is the use of machinery that is not suitable for the kind of rice harvested.

Storing shows a share of 1.05 percent of rice losses. The respondents in the current survey summarized that structural characteristics of the garners are behind the losses of rice during the storing. Sometimes garners are too small to contain all the packed rice; as a consequence, the packs of rice are stored without respecting the minimum required distance between one package and the other. In some other garners, lack of air conditioning systems facilitates the attacks from insects and parasites. For either short-term or long-term storage, rice should be given some air to breathe in order to prevent spoilage.

The packaging is the other most inefficient process with respect to rice losses. This process takes place just in the processing stage and it generates 0.51 percent of rice losses. The lowest losses occur in transporting with 0.05 percent of rice losses. An old-fashioned packing industry is behind the losses of rice during packaging and transporting. Rice is mostly packed in cotton and plastic bags and they are not vacuumed. Various modifications including aluminum foil, lamination or paper bags within the rice packaging design can be added to the rice packaging, making it more convenient and efficient in reducing losses.

The last part of this section aims at broadening the findings of this study by estimating the quantity of rice losses and their economic value beyond the studied case. The data discussed below combine the figures emerging from this study about the losses of rice in some rice chains located in Mazandaran province; Qaemshahr city with figures retrieved at the FAO website concerning the total production, imports and exports, producer prices, and per capita consumption of rice in Iran. Table 3 reports figures from FAOSTAT, while Table 4 combines these figures with some of the data gathered by this study using the basic mathematics equations reported in Table 1.

Annually, around 3,872 thousand tons of rice is consumed in Iran (Table 4). This figure is derived as the sum of the tons of rice imported and produced minus the tons of rice exported on a yearly basis (Table 3). Around 797 thousand tons of produced rice is annually lost in Iran (Table 4). This figure results from multiplying the tons of rice produced in Iran per year (Table 3) by the percentage of rice losses (0.29%) estimated by this study for the main rice production area. As this percentage is close to the 0.30 percent of grain production losses estimated by FAO for the southwest of Asia, therefore, we consider our estimation of losses as an appropriate proxy of the percentage of rice losses for the entire country. This amount of losses of rice corresponds to an economic loss of 714 million U.S. dollars, which is derived by multiplying the tons of rice lost in Iran times the price paid to rice producers. On the other hand, we estimate that 689 million U.S. dollars are paid to import rice for compensating the excess demand in the country. This amount is derived by dividing the import value by the imported quantity, which gives back the price of the rice imported. The final economic value for imported rice is obtained by multiplying its price by the tons of rice imported. Summing up, 1,403 million U.S. dollars are missed annually in Iran because of rice losses. In the Eastern and Southern Africa only, post-harvest losses are valued at 1.6 billion U.S. dollars for every year (Obeng-Ofori, 2011). Finally, from the food security aspect, if we consider the amount of rice losses divided by the rice supplied per capita, we obtain that 18 million people per year could be fed with the amount of lost rice.

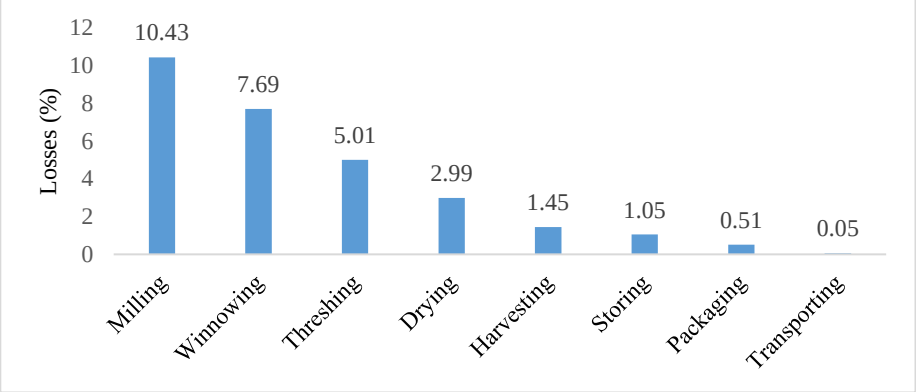

Fig. 3. Percentage of rice lost during different processes in the rice supply chain

Table 3. Figures about rice production, import, export, and producer price in Iran

Items	Quantity	Units
Production quantity	2,75	1000 tons/year
Import quantity	1,13	1000 tons/year
Export quantity	110	tons/year
Import value	973,29	1000 US$/year
Producer price	896	US$/tons
Import price	865	USD$/tons
Rice supply	43.80	kg/capita/year

Table 4. Estimated quantity and economic value of rice losses in Iran

Item	Quantity	Units
Consumption quantity	3,87	1000 tons/year
Losses quantity	797	1000 tons/year
Value of rice lost	714	million US$/year
The value assigned to import the quantity of rice lost	689	million US$/year
Total missed value	1,403	million US$/year
Number of People can feed with the lost rice	18	million/year

Summing up, according to what emerges from the data gathered in this study, the supply chain of rice in the most important rice production areas in Iran is inefficient in producing and supplying rice as around one-third of the produced rice is lost from farming to retailing. Most of the losses occur at the farming and processing stages of the chain. Traditional and inappropriate technologies to produced rice, lack of knowledge on how to use appropriate technologies, and lack of financial resources are behind rice losses in the rice chain in Iran. Hence, the actions that can be taken to tackle rice losses should mostly consider investing in agricultural technologies especially at the farming and processing stages, and improving knowledge sharing among the actors involved in the rice supply chain.

CONCLUSION

Food losses affect the sustainability of food systems and their ability to ensure food security. This paper has highlighted some relevant figures about rice losses in Iran. It has been found in this study that approximately one-third of the total rice production is lost from producers to consumers because of inefficient delivery from producer to consumer. This amount could feed 18 million people per year. On the other hand, it requires the use of resources, such as water, which are limited in Iran. The rice losses imply an economic loss of 1,403 million U.S. dollars hence, the potential benefits of reducing rice losses are, at least, threefold. It would allow improving food security as food availability would be increased. At the same time, it will reduce the environmental impact of rice production by reducing the needlessness of natural resources, which are already scarce, to produce food that is not consumed. Last, but not least, it would allow for the more economically efficient rice supply chain as it would avoid investing economic resources in producing, distributing, and retailing product that will not reach consumers. Mainly, decreasing food losses is an effective way to rise the efficiency and sustainability of food systems and reduce the environmental effect of food consumption. To reduce losses in order to increase the sustainability of food systems and improve food security, policy-makers have to consider useful innovations throughout the entire food chain involving all the actors. Economic and social innovations in the supply chains appear to be the most important essential. Financial support of the actors as an economic innovation will help the actors to improve the technologies and infrastructures used in the entire supply chains and then will improve the sustainability of the food systems to achieve food security. On the other hand, educating all the actors who are active in the food supply chains about how to use the new technologies, how to save food, etc. must be noticed, as social innovation. It is received from the literature on the issue of food losses that there is a lack of useful data to estimate the scale of food losses and identify the real causes. In addition to suggestions of Sheahan and Barrett (2017); future studies should focus on the ways to collect the useful and more accurate data in order to find the most important reasons of food losses in each stage and process of the food supply chains considering economic, environmental, and social issues.

Conflict of interest

The authors have no conflict of interest to report.

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