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Management of Iceberg Lettuce Quality

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

In this study, an attempt has been made to understand the quality deterioration of iceberg lettuce during its supply chain i.e. during the pre-harvesting, harvesting and post-harvesting period. Further, it was tried to identify the cost of cultivation of iceberg lettuce per hectare and the crop rotation followed by the farmers. The Nilgiris District of the Tamilnadu state was the study area for this research. For this study, 30 farmers were selected for data collection based on convenience sampling. From these farmers during the pre-harvesting, harvesting and post-harvesting period every 10 samples of iceberg lettuce heads were taken for inspection and observations were recorded during quality inspection. From the study, it was found that the major part of the quality deterioration takes place during the post-harvest period. This paper focused on the comparison of the quality parameters done before dispatch and after, the knowledge of iceberg lettuce growing farmers. It was identified for the chemical application the spraying techniques used for the growing of iceberg lettuce. These current practices of farmers for the chemical application and spraying techniques are compared with the standard practices to identify the loopholes in the current practices of the farmers. It was found that the total cost of cultivation was 66495 rupees/acre.

Keywords: Iceberg lettuce; quality; farmers; harvest; techniques and cost.

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1. INTRODUCTION

Lettuce (*Lactuca sativa*), a vegetable that belongs to the Asteraceae family, is popularly grown and consumed worldwide. The leaves are nutritious and contain more minerals and carotenoids, including beta-carotene. It adds fewer calories but contains more water, some fiber and folate. One of the most popular fresh vegetables, iceberg lettuce is frequently used in salads, sandwiches, and other dishes in self-service restaurants. However, it is well recognized that iceberg lettuce's quality rapidly deteriorates at room temperature, severely restricting the vegetable's storage and consumption. The application of various treatments may prevent the deterioration of vegetable quality after harvest. As per the FAO [1] Report 17228 tonnes of lettuce and chicory are produced worldwide.

In the study of Fan et al. [2] The lettuce that was irradiated at 0.5 or 1 kGy and treated with warm water had the greatest sensory quality with no appreciable loss in texture, vitamin C, as well as total antioxidants.

The results of Johannessen et al. [3] revealed that the bacteriological integrity of organic lettuce is not significantly affected by the usage of manure. Others, however, have asserted that utilising manure carries a danger. Fonseca et al. [4] identified that Sprinkle irrigation has been shown to increase the risk of E. coli infection under typical commercial circumstances. Additionally, the persistence of E. coli in soil that has been furrow-irrigated confirms the value of early irrigation termination for both sprinkler and furrow techniques. Agüero et al. [5] studied the middle and external sections' overall quality scores fell below the acceptable limit and only the internal section had a scoring rate above the limit, the material's quality and shelf life was determined to be five days. Additionally, lettuce's general quality declined gradually when kept at the ideal RH level.

In this study, an attempt is made to understand the quality deterioration of iceberg lettuce during its supply chain i.e. during the pre-harvesting, harvesting and post-harvesting period. Further, it was tried to identify the cost of cultivation of iceberg lettuce per hectare and the crop rotation followed by the farmers.

1.1 Management of Iceberg Lettuce Quality

1.1.1 Pre-harvest Period

Harvest maturity: harvesting at optimal maturity, concerning achieving maximum yield and shelf-life. Martínez-Romero [6] suggested that the natural fungicide may be a fantastic solution for synthetic fungicides to meet consumer expectations for more natural and healthy meals.

Irrigation management: Trickle irrigation, which uses less water than sprinkler irrigation, may be used to successfully cultivate lettuce. Up to harvest, lettuce plants should be kept free of water stress for maximum yields.

Planting density: To calculate the planting density and amount of fertilizer to apply to enhance yields per hectare.

The study of Tudela et al. [7] suggested that Fresh-cut iceberg lettuce's aesthetic appeal is crucial, but so are its aroma and flavor. To prevent off-odors and create superior fragrance and flavor attributes for maintaining the "freshness" of the cut product, the MAP presently used for fresh-cut lettuce may require some adjustment. It is advised to screen for cultivars with minimal browning potential and fermentation, picked at the ideal period of maturity, and with an appropriate packaging design.

1.1.2 Post-harvest period

The commercial life of lettuce will be shortened if it is harvested too early or too late. Harvesting early indicates that fewer carbohydrates have been stored, whereas harvesting late indicates that the field has already begun to age.

1.1.3 Cooling/temperature control

If lettuce is vacuum cooled within 30 minutes of harvest, the product will have the longest possible shelf life. It is not advised to chill lettuce using forced air since it is a sluggish cooling method. For optimal performance, the cool chain needs to be kept in place from the farm gate to the customer.

1.1.4 Store lettuce as close to 0ºC as possible

Low-temperature storage lowers the product's respiration rate, which lowers the pace of

degradation, metabolism, and root formation. During harvest and handling, avoid damage: After harvest, damage encourages browning and rots. After harvest, lettuce's marketable life can be increased by removing the outer leaves. A dependable cool chain is a crucial element that shouldn't be disregarded. Breaks in the cool chain can destroy all the hard work done on a farm. Mou and Boiguan [8] studied that environmental elements such as light, temperature, growing season, cultural techniques, fertiliser application, post-harvest processing, and storage conditions may have an impact on the nutritional quality of lettuce. The plant's moisture level also interferes with the absorption of nutrients. Enhancing the nutritional value of vegetables would boost nutrient intake without necessitating an increase in intake [9-11].

Iceberg lettuce is mostly preferred for consumption in foreign countries in the form of salad. In worldwide production, India is on 3rd position but with the comparison of worldwide area, production and yield India is far behind (Fig. 1).

This anomalous vegetable became more well-known in India from some previous ages. Growing exotic vegetables like lettuce, broccoli, parsley and red cabbage have great scope and created cultivation interest among Indian farmers [12,13]. The consumption is increasing day by day as India imports more than 85 percent of the exotic vegetables (Fig. 2). Contrasting to Indian vegetables, the production of anomalous fruits and vegetables has become a lucrative business in some parts of India.

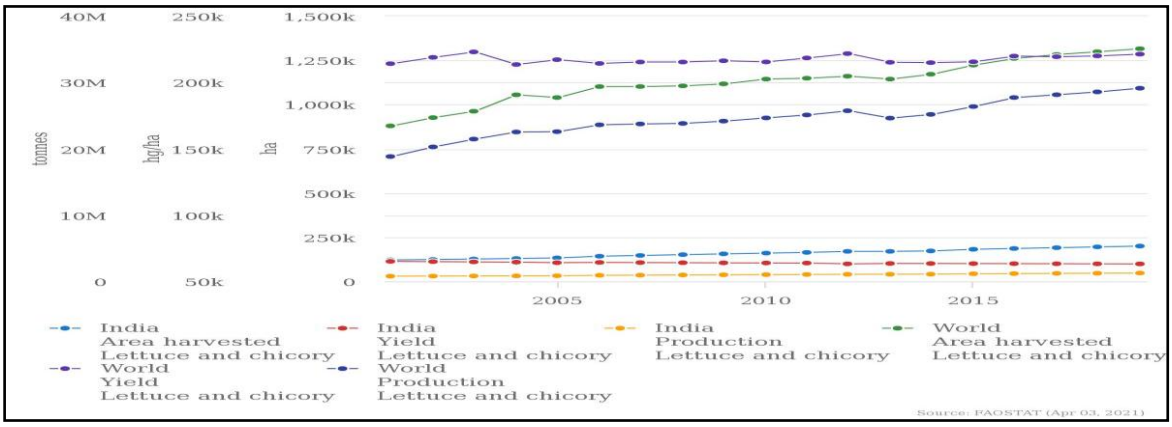

Fig. 1. Area, Production and Yield of Lettuce and Chicory in World and India Comparison
Source: FAOSTAT (2017)

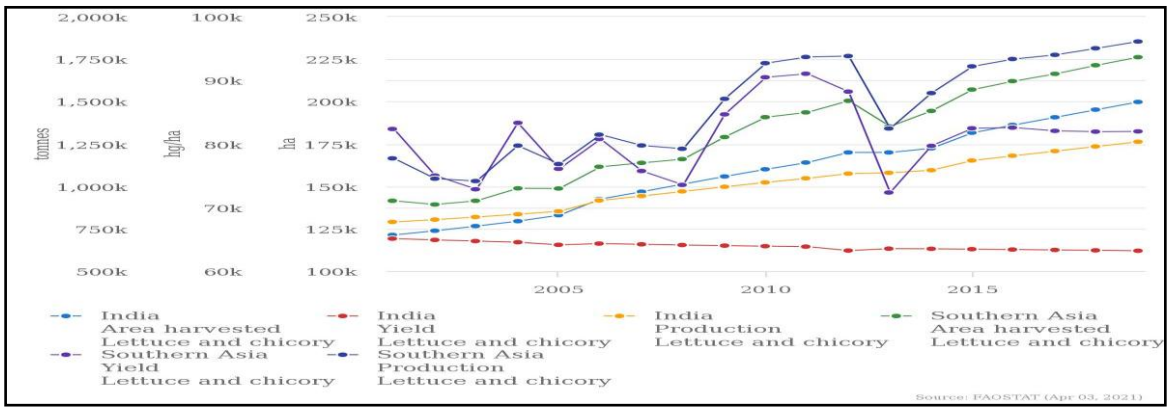

Fig. 2. Area, Production and Yield of Lettuce and Chicory in South Asia and India Comparison
Source: FAOSTAT (2017)

2. LITERATURE REVIEW

2.1 Empirical Review on the Impact of Different Chemicals on Iceberg Lettuce Quality

Numerous researches have been carried out to determine the effects of various chemicals on the quality of iceberg lettuce globally. The results of Gopal et al. [14] revealed that silver nitrate and electrochemical silver both had equal disinfectant properties, electrochemical silver preserved the quality of washed vegetables. Hoque et al. [15] identified that the combination of 225 kg/ha N and 112 kg/ha P was the most affordable treatment that produced the highest yield and best post-harvest quality. In a study conducted by Konstantapoulou et al. [16] researchers in south Greece concluded that 200 mg NL-1 is the ideal nitrogen application rate for growing Cos lettuce hydroponically under cover during the fall and winter, as well as in other regions with a similar climate. At this nitrogen rate, the yield is satisfactory, and leaf nitrate concentrates are below the upper limit that is safe for human consumption. Similar to that, salads of fresh-cut Romaine and Iceberg lettuce from various commercial brands were purchased from both retail and wholesale establishments. The packages were opened at one end, the lettuce salad was sprayed with a fine mist spray to inoculate it with E. coli O157:H7, and then they were resealed either with or without an initial N2 flush to match the original package atmospheric conditions. A study by Luna et al. [17] found that on six distinct harvest dates over three consecutive years, the effects of five drip irrigation methods on the quality and shelf life of fresh-cut iceberg lettuce (*Lactuca sativa* L.) were investigated. By cutting back on irrigation during the growing season, the fresh-cut lettuce's freshness and shelf life were better protected. The study of Palma-Salgado et al. [18] found that In treatments using simply a sanitizer, the washing-before-cutting approach obtained an E. coli O157:H7 count reduction that was 0.79–0.80 log10 CFU/g greater than that attained with the cutting-before-washing process. With the addition of ultrasound to the washing-before-cutting procedure, microbial count reductions increased by 0.37–0.68 log10 CFU/g, achieving final reductions of 2.43 and 2.24 log10 CFU/g for washes with chlorine and peroxyacetic acid, respectively. In treatments using simply a sanitizer, the washing-before-cutting approach obtained an E. coli O157:H7 count reduction that was 0.79–0.80 log10 CFU/g greater than that attained with the cutting-before-washing process. With the addition of ultrasound to the washing-before-cutting procedure, microbial count reductions increased by 0.37–0.68 log10 CFU/g, achieving final reductions of 2.43 and 2.24 log10 CFU/g for washes with chlorine and peroxyacetic acid, respectively. 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In treatments using simply a sanitizer, the washing-before-cutting approach obtained an E. coli O157:H7 count reduction that was 0.79–0.80 log10 CFU/g greater than that attained with the cutting-before-washing process. With the addition of ultrasound to the washing-before-cutting procedure, microbial count reductions increased by 0.37–0.68 log10 CFU/g, achieving final reductions of 2.43 and 2.24 log10 CFU/g for washes with chlorine and peroxyacetic acid, respectively. A study by Galgano et al. [19] the fresh-cut iceberg lettuce's shelf life, comparing packaging films made with and without anti-UV additives, and utilising two different protective atmospheres (N2 / 2 70/30% and Ar/ 2 80/20%). The samples were kept at 6 °C under artificial lighting on genuine supermarket refrigerated exposition stands to mimic the most typical retail storage settings. However, the greatest results were achieved when the anti-UV film was used in conjunction with the packing environment consisting of Ar and 2 (80/20%) gas combination. The data revealed that the use of an anti-UV film always produces a lesser quality degradation of the product. In the study Cavallo et al. [20] shows that the suggested method may be widely used to assess the performance levels of freshly cut lettuce independent of packaging at all of the other important road blocks parallel to the longitudinal supply chain because the

performance loss affected by the addition of packaging is minor (83 percent instead of 86 percent).

3. MATERIALS AND METHODS

The Nilgiris District of the Tamilnadu state was the study area for this research. Iceberg lettuce cultivation in Tamil Nadu is practiced in this district. The reason for selecting the Nilgiris district was that the area was more prominent and suitable for the production of quality Iceberg lettuce. The climatic condition of the Blue Mountains is perfect for the cultivation of exotic vegetables like Iceberg lettuce, broccoli, beetroot, leeks, Chinese cabbage, etc. As Iceberg lettuce requires a cold climate and the climate of Nilgiris is suitable for Iceberg production. In the Nilgiris district, several private companies are doing contract farming to produce Iceberg Lettuce. For this study, 30 farmers were selected based on convenience sampling. From these farmers, during the pre-harvesting, harvesting and post-harvesting period every 10 samples of iceberg lettuce heads were taken for inspection and observations were recorded during quality inspection. A structured schedule was used for data collection. For this study, fields were visited on the weekly basis to check the insect load and other parameters like rotting, diseases, etc. Visiting the harvesting fields to monitor the GHPs (Good Harvesting Practices) like wearing the hairnet, gloves, using sanitized knives, etc.

4. RESULTS

4.1 Quality Inspection during Pre-Harvesting, Harvesting and Post-Harvesting Period

The maintenance of the quality and shelf life of the iceberg lettuce is important between the periods of its production point until it reaches the ultimate consumer. To identify the changes observed in the quality of the iceberg lettuce during the pre-harvesting, harvesting and post-harvesting period of its life cycle.

During the pre-harvesting Period:

A visit to the iceberg lettuce is taken, which will be harvested in the next week to analyze the condition of the field. Careful observation of the iceberg lettuce was done to identify some defects like Rotting, insect pest attack, various diseases and improper head formation. Apart from the external observation, ten iceberg lettuce heads were collected randomly from the different parts of the fields to inspect those sample heads' quality. After the field observation and quality inspection of 10 heads, a report was prepared to comprise the field observations and the observations made during the quality inspection of 10 iceberg lettuce.

During the harvesting period based on the prior observations are done, the instructions regarding Good Harvesting Practices (GHPs) like maintaining sufficient stem length, outer dark green layers removal and placement of heads (to reduce the browning effect on the outer surface of the heads during transportation) were given to the harvesting team about how to harvest the fields. For example, if the field is severely infested with rotten pieces, the harvesting team was instructed to carefully see the head and cut the rotten free heads.

During Post-harvesting Period:

At the dispatch center, the harvested produce was pre-cooled for two hours at 4-5°C. After pre-cooling, the produce was unloaded from the cold storage and loaded into the refer vehicle, which will further supply the produce to the processing unit. During the quality inspection during the post-harvest period, 20 samples were taken from different crates, which will be dispatched on that day. After selecting the 20 samples, they undergo a quality inspection process, in which some quality parameters like Maturity Index (Maturity index represents the correct maturity of iceberg lettuce. The maturity index is the density or compactness of inner layers within a head), Insect load (Insect load is the number of insect pests found within the heads during quality inspection), Browning (Browning will happen because of the friction between the iceberg lettuce heads during transportation), Rotting (the rotten portion of all the iceberg lettuce heads is cut off and weighed separately.) and Outer dark green layer (the outer dark green layers should be removed as they are of no use) were tested for quality determination.

Table 1 shows the difference between the Quality Index Parameters (QIP includes the parameters like head size, browning percentage, rottening percentage and insect load percentage) at the time of dispatch and at the time of receiving at Mumbai location.

Fig. 3. Caterpillar Infestation

Fig. 4. Rotting

Fig. 5. Improper Head Formation

Fig. 6. Leaf Minor Infestation

Table 1. Difference between the QIP at the Time of Dispatch and At the Time of Receiving at Mumbai

Quality Parameters (Avg)	30/05/2015		02/06/2017		05/06/2017		10/06/2017		15/06/2017	
	Disp		Rec		Disp		Rec		Disp	
Head Size (gm)	522	410	545	510	502	420	360	420	560	550
Browning (%)	0.8	2.3	2.4	5.1	1.8	5.2	0	0	0.7	2.1
Rottening (%)	1.4	4.3	0	0	0	0	0	0	0	0
Insect Load (%)	0	0.15	0.25	0.07	0	0.24	0.33	0.12	1.25	0.19

Source: Primary data

Table 2. Difference between the QIP at the Time Dispatch and at the time of Receiving at Bangalore

	9/06/2017		14/06/2017		19/06/2017	
	Disp	Rec	Disp	Rec	Disp	Rec
Head Size(gm)	428	330	500	430	550	430
Browning (%)	1	1.5	0.1	1.5	0.3	1.5
Rottening (%)	0.3	2	0.5	2	0.2	2
Insect Load (%)	0.3	1	0	0.1	0	0.16

Source: Primary data

Table 2 shows the difference between the QIP (QIP includes the parameters like head size, browning percentage, rottening percentage and insect load percentage) at the time of dispatch and at the time of receiving at Bangalore location.

4.2 Cost of Cultivation and Crop Rotation Followed by the Iceberg Lettuce Farmers

For calculation of standard cost of cultivation per acre and crop rotation practices related data were collected.

The cost associated with field preparation is ₹ 14700/- which is done before showing. Then further cost associated with seed transplanting, irrigation, weeding, pesticide application is ₹ 19950, 70, 2100 and ₹ 2760 respectively (Table 3). The irrigation given to crop is 10 to 15 days interval. The cost associated with fustigation is ₹ 21465 which is given in split doses at different days as shown in Table 3. If properly managed, the estimated cost of cultivation for iceberg lettuce per acre would be around ₹ 67000. The data has been collected from the company and it is the standard cost of cultivation which is cost-effective with more production. As contract farming is going on in the study area, the average cost of cultivation of the farmer is also around ₹ 67000. The contract farming company is providing the necessary tools like insect traps, yellow sticky traps and chemicals for application to control insect pests and diseases. Hence farmers are purchasing very little amount of other chemicals and tools which are necessary for the cultivation of iceberg lettuce.

Hence the cost of cultivation of iceberg lettuce growing farmers' in the study area is almost similar and is around ₹ 67000. The contract farming company is also monitoring the field activities of the iceberg lettuce growing farmers to obtain the uniform and best yield possible.

4.3 Crop Rotation Followed by the Iceberg Lettuce Farmers

From Fig. 7, it can be interpreted that there are two types of crop rotations followed by the iceberg lettuce growing farmers in the study area. It can be noticed that after every crop the farmers are taking a one-month gap for land preparation and other activities. Of the above types of crop rotation, the type one crop rotation is followed by the majority of farmers i.e. 90 percent and only 10 percent of farmers are following the type two crop rotation.

Table 3. Cost of Cultivation of Iceberg Lettuce

Days	Field preparation	Seed material & transplanting	Irrigation	Weeding	Pesticide application	Fertilizer application	Harvesting
1	14700						
5		19950	500				
10					920		
20			500	1050		550	
25						10125	
33			500		920		
35				1050		3150	
38			500			550	
40					920	920	
42						3200	
58						2970	
Total	14700	19950	2000	2100	2760	21465	3400

Source: Primary data
Machinery hiring charges per day – 2250
Grand Total – ₹ 66745/Acre

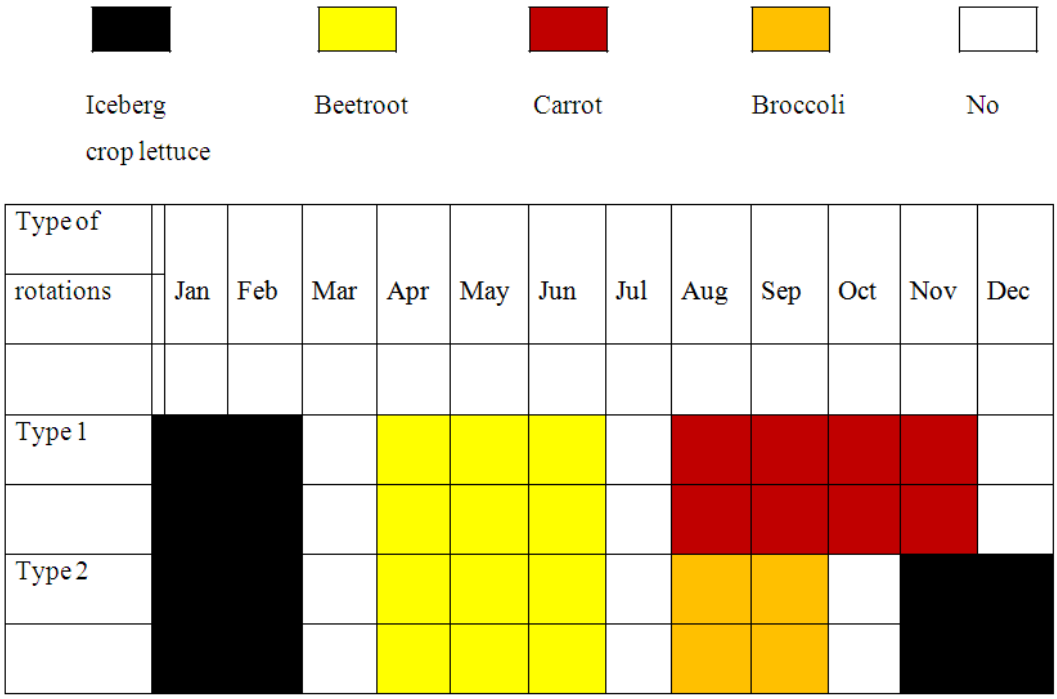

Fig. 7. Crop Rotation
Source: Primary data

5. CONCLUSION

5.1 Quality Inspection

- While harvesting, the harvesting team is not maintaining the sufficient stem length and because of that the outer two to three layers were falling off during transportation which ultimately results in higher weight shrinkage during transportation.
- The placement of heads in the crates is not always correct in both situations i.e. during harvesting and dispatching. Because of this, the browning problem has been observed frequently during transportation
- The crates in which the heads are being placed must be free from all types of dust and wastage but as per the observations in the study area, the crates were not clean and there are always clay spots and streaks of the lettuces.
- According to the Good Harvesting Practices (GHPs) laid down by the company, the hairnet and gloves must be used while harvesting. But the harvesting team members are not using hair nets while harvesting.
- There is also a protocol that during loading and unloading the iceberg lettuce, gloves should be used to eliminate human direct contact with the product, but this rule is not properly monitored by the dispatch unit.

5.2 Cost of Cultivation and Crop Rotation

- The total cost of cultivation was 66495 rupees/acre.
- As per the data collected in the study area, two types of crop rotations are being followed by the iceberg lettuce farmers namely,

  - Iceberg lettuce followed by beetroot followed by carrot
  - Iceberg lettuce followed by beetroot followed by broccoli followed by iceberg lettuce

6. RECOMMENDATIONS

As the new members have joined the harvesting team, they are not aware of leaving sufficient stem length of iceberg lettuce. Hence there is a need for a training programme for the new members of the harvesting team about Good Harvesting Practices (GHPs). The crates in which the iceberg lettuce heads are placed must be free from all types of dust and dirt to maintain cleanliness and prevent contamination. The harvesting team members must be provided with

the hairnet and gloves during harvesting. And during loading and unloading also the labors must be provided with gloves and hairnet. Crop rotation should be followed by farmers which are good for better production of iceberg lettuce.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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