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Effect of Modified Atmosphere Package on Chemicals and Sensory Qualities of Pomegranate Fruits under Low Temperature Storage

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ABSTRACT: Pomegranate fruits are nutrient dense, attractive, appealing and are popular across the region and demographics. The fruits are good source of vitamin C, antioxidants and polyphenols and hence commands excellent marketability. Consumers' increasing demand is of convenient and fresh quality fruits. The modified atmosphere packaging technology thus has been designed to maintain the nutritional and sensory quality and to enhance the storage life of pomegranate fruit. Studies were conducted to investigate the effect of modified atmosphere packaging (MAP) materials on ascorbic acid, total anthocyanin, antioxidant property and sensory qualities of pomegranate fruits under low temperature storage. Fruits were picked up from field, cleansed with sodium hypochlorite and dried. Later, they were categorized and fruits of uniform size were selected. Various types of packaging materials *viz.* polyethylene, polypropylene, Xtend® bags and Silver nano bags were used for packing the fruits. Unpacked fruits were served as control. These fruits were stored at a temperature ± 2°C and RH of 7 90 ± 5% till 100 days. The results revealed that ascorbic acid and total anthocyanin contents were maximum at 40 days of storage whereas, total antioxidant activity was maximum at 60 days of storage in Silver nano bags compare to the other packaging materials. The sensory qualities such as colour, texture, taste and general acceptability declined in all the treatments with extended storage, however, the rate of decrease was minimum in MAP and was maximum in control fruits. The MAP stored fruits had extended market ability up to 100 days compared to unpacked fruits that had only up to 40 days. Thus the MAP could be useful in prolonging the period of fruit availability over large geographical area to the consumers and benefit both growers and consumers.

Keywords: Anthocyanin, Ascorbic acid, MAP, Pomegranate, Sensory quality, Storage.

INTRODUCTION

Pomegranate is one of the most desired fruit crops globally. The fruits are by and large consumed fresh by extracting the arils or utilized as processed products *viz*., juice, yoghurts, syrup, grenadine, anardana, anar-rub, jam, jelly, wine, carbonated beverage *etc*. However, removal of the edible arils from the fruit is laborious task. In addition, the fruit has many constraints for its direct consumption contrary to the other fruits like oranges, banana, grapes and others (Pal and Gaikwad, 2014). Pomegranate fruit is a non-climacteric having comparatively less respiration rate and produces trace amounts of ethylene (Caleb *et al*., 2012). Normally, the storage life of the fruit is quite good varying from 2 to 7 months that goes with type of cultivars and storage facilities. The cultivar 'Bhagwa' from India has gained wide acceptability because the arils are soft and deep red and hence it is common among the exported cultivars; mainly preferred by the countries like UK, Holland, Malaysia and Singapore. The main constraints in exporting fruit is the short shelf life which can be mitigated by increasing the storage period without compromising on the quality during storage as well as transport. Numerous postharvest techniques are available to meet the consumers' preference for fresh, natural with good flovour and of high quality fruits. One such technique is modified atmosphere packaging combined with low temperature storage conditions that has been extensively used for the improvement of the shelf life without compromising on the quality of fruits. Modified atmosphere package (MAP) films improve the shelf life of many fruits by altering the fruit's internal atmosphere of the fruits (Kader *et al*., 1989). MAP is thus most sought after in extending the storage period of fresh fruit by reducing weight loss and browning and extending the marketability (Beaudry, 2000). With this background an experiment was conducted to study the effect of modified atmosphere packaging on chemicals and sensory qualities of pomegranate fruits during storage.

MATERIAL AND METHODS

The pomegranate fruits (*cv*. Bhagwa) were harvested at maturity stage directly from the field and transported on the same day to Department of Postharvest Technology, College of Horticulture, University of Horticultural Sciences Campus, GKVK, Bengaluru, India in 2018 for the experiment. Fruits were cleansed with sodium hypochlorite (150 ppm), washed in running tap water and later air dried to remove surface water. The uniform 15-20 number fruits weighing 4-5 kg were packed in modified atmosphere package bags *viz.*, Polyethylene bag (T_1): Polypropylene bag(T_2): Xtend® bag (T_3): Silver nano bag Hima Fresh®(T_4) along with control unpack (T_5) and kept in corrugated fiberboard boxes as per treatment and stored at low temperature 7 ± 2°C and 90 ± 5% relative humidity. Experiment was conducted statistically using completely randomized design with five treatments and five replications. The fruits were analyzed for ascorbic acid content, total anthocyanin and total antioxidants contents at 20-day interval. They were further evaluated for the sensory qualities *viz*., colour, texture, taste and overall acceptability. For evaluation of shelf life, the fruits were removed from the cold storage and also from the packages and kept at ambient conditions.

The Ascorbic acid content of fruit samples was determined using 2, 6-dichlorophenol indophenol sodium salt (AOAC, 2006). The total monomeric anthocyanin content was estimated by employing the pH differential method (Giusti and Wrolstad, 2001) whereas, the total antioxidant activity of pomegranate fruits was determined by the FRAP method (Benzie and Strain, 1996).

Sensory evaluation of pomegranate fruits was done at 20-day interval for the various attributes *viz*., colour, texture, taste and overall acceptability. For this evaluation, a panel consisting of ten judges of semi trained was selected and the qualities were assessed by applying the nine point Hedonic scale (Amerine *et al*., 1965) where 9-Excellent; 8-Extremely good; 7-Very good; 6-Moderately good; 5-Good; 4-Very fair; 3- Fair; 2-Poor; 1-Very poor. The data obtained were subjected to statistical analysis as per the guidelines suggested by Panse and Sukhatme (1978).

RESULTS AND DISCUSSION

A. Chemical qualities

The ascorbic acid of pomegranate fruits in all the treatments decreased with prolonged storage as shown in Table 1. Significant differences were recorded among treatments. The fruits packed in Silver nano bags had maximum ascorbic acid content (11.60 mg $100g^{-1}$) followed by polypropylene (11.47 mg $100g^{-1}$) while, it was least (11.05 mg $100g^{-1}$) in unpacked fruits at 40 days of storage. The same trend continued till 100 days of storage, where, highest ascorbic acid content (10.46 mg $100g^{-1}$) was observed in the fruits packed in Silver nano bags whereas, it was least (10.09 mg 100 g^{-1}) in the fruits packed in Xtend® bags. The results are in confirmation with the studies carried out by Naik *et al.*, (2017) who noticed reduction in ascorbic acid content in pomegranate fruits with increase in storage period. The reduction in ascorbic content might be due to the oxidative enzymes' activity *viz*., ascorbic acid oxidase, peroxidase, catalase and polyphenol oxidase (Singh and Sudhakar Rao, 2005) and also due to the oxidative reduction of vitamin C by the enzyme ascorbic acid oxidase (Pruthi *et al*., 1984). Even the ripening process leads to reduction of ascorbic acid which happens owing to oxidation of L-ascorbic acid tode hydro ascorbic acid (Mapson, 1970). Another reason for the lower ascorbic acid retention in MAP treated fruit might be due to delayed biosynthesis or fast degradation of ascorbic acid. The effect of elevated CO_2 on ascorbic acid content depend on the fruit, CO_2 levels, storage temperatures and durations generally, high CO_2 levels in the MAP storage atmosphere cause a degradation of ascorbic acid (Lee and Kader, 2000). It is also stated that ascorbic acid is light liable, thermo liable and subjected to oxidation loss during storage. Each storage day causes reduction in ascorbic acid.

Table 1: Effect of MAP on ascorbic acid of pomegranate fruits stored under low temperature (7 ± 2°C).

Treatment	Ascorbic acid (mg $100g^{-1}$)				
	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS
T_1- Polyethylene bags	11.57	11.39	11.16	10.68	10.10
T_2- Polypropylene bags	11.62	11.47	11.35	10.75	10.39
T_3- Xtend®bags	11.53	11.32	10.99	10.43	10.09
T_4- Silver nano bags	11.72	11.60	11.46	11.03	10.46
T_5- Control (unpack)	11.43	11.05	--	--	--
S. Em ±	0.076	0.060	0.065	0.144	0.111
CD @ 5%	0.107	0.177	0.194	0.431	0.333

* Significant at 5% level NS: Non significance at 5% level DAS: Days after storage
--: End of storage life, D0 Ascorbic acid: 11.80 mg $100g^{-1}$

The anthocyanin content (Table 2) indicated that there was initial increase in the anthocyanin content followed by decrease with prolonged storage. Significant differences were recorded among treatments. The anthocyanin content in pomegranate fruits increased initially till 60days and then decreased with storage up to 100 days after storage. The anthocyanin content at 40 days of storage was highest (21.72 mg 100 ml^{-1}) in unpacked fruits followed by Xtend® bags (21.66 mg 100 ml^{-1}), while it was least (20.14 mg 100 ml^{-1}) in the fruits packed in Silver nano bags. The same pattern continued till 100 days of storage, where maximum anthocyanin content (19.43 mg 100 ml^{-1}) was observed in Xtend® bags and least (16.06) was recorded in Silver nano bags. The results are in agreement with the findings of Artés *et al*., (2000) who observed an increase in total anthocyanin content stored in perforated polypropylene film and control fruit at 5°C and then decrease in total anthocyanin content. Caleb *et al.,* (2013); Dhineshkumar *et al*., (2017) reported a decrease in total anthocyanin content of pomegranate arils with increase in storage time. The increase in the initial days of storage is the result of continued biosynthesis of phenolic compounds after harvest and due to increase in the activity of the enzymes during anthocyanin biosynthetic pathway (Gil *et al*., 1996; Holcroft *et al*., 1998). The enzymatic oxidation of anthocyanin compounds might be the reason for the reduction in anthocyanin during storage in pomegranates (Jiang and Chen, 1995). Selcuk and Erkan (2014) also gave the same reason for an initial increase in anthocyanin content followed by a decrease during storage. However, wrapping fruits and fludioxonil application resulted in fairly stable antioxidant capacity in all treatments during cold storage (D'Aquino *et al.,* 2010).

Table 2: Effect of MAP on anthocyanin content of pomegranate fruits stored under low temperature (7±2°C).

Treatment	Anthocyanin content (mg 100 ml^{-1})				
	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS
T_1- Polyethylene bags	19.43	21.02	22.86	21.13	18.48
T_2- Polypropylene bags	19.25	20.82	21.54	20.68	16.22
T_3- Xtend®bags	19.47	21.66	23.13	21.23	19.43
T_4- Silver nano bags	19.23	20.14	20.64	19.61	16.06
T_5- Control (unpack)	19.53	21.72	--	--	--
S. Em ±	0.287	0.284	0.230	0.269	0.231
CD @ 5%	0.846	0.837	0.688	0.805	0.692

* Significant at 5% level; DAS: Days after storage; --: End of storage life; D0 Anthocyanin content: 18.57 mg 100 ml^{-1}

The results of our studies indicated about the increase in the antioxidant activity of the pomegranate fruits up to 60 days then decreased of up to 100 days of storage (Table 3). The treatments differed significantly with respect to antioxidant activity at 20 and 40 days after storage. The antioxidant activity was highest (56.64 mg AEAC 100 ml^{-1}) in pomegranate fruits packed in Silver nano bags, while it was least (56.28 mg AEAC 100 ml^{-1}) in unpacked fruits at 40 days of storage. This trend remained same even for the fruits stored till 100 days, where maximum antioxidant activity (56.26 mg AEAC 100 ml^{-1}) was observed in fruits packed in Silver nano bags, while it was minimum (55.91 mg AEAC 100 ml^{-1}) in the fruits packed in Xtend® bags. The results of Ayhan and Eştürk (2009), on antioxidant activity getting increased in pomegranate arils up to 9-day of storage and subsequently decreasing under passive and active MAP having less or no O_2 are in agreement with our results. Dhineshkumar *et al.*, (2017) also reported increase in antioxidant activity of pomegranate arils processed minimally till 9 days and after which it showed declining pattern during entire storage period. Significant differences at 20 and 40 days of storage may be due to more loss of ascorbic acid, phenolic compound, moisture, respiration rate in packed fruits. Bhatia *et al.* (2015) studied on different packing material on arils of pomegranate *cv*. Mridula stored at 5 ± 2°C and 85±5% RH for 15 days and the results revealed that arils packed in PP bags retained better antioxidants activities compared to LDPE pack upto the 15 days of storage. However, Violeta *et al*., (2005) did not found significant difference in the antioxidant activity of pomegranate arils obtained from the fresh fruits and the stored fruits.

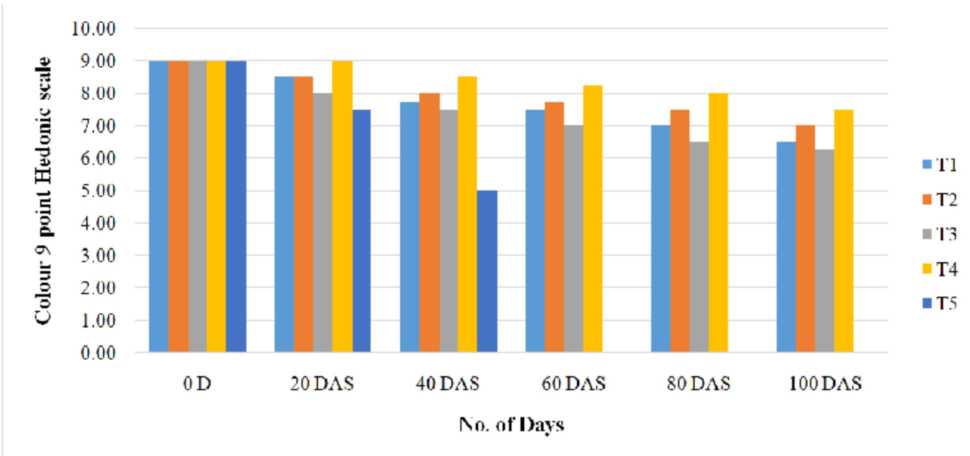
Table 3: Effect of MAP on antioxidant of pomegranate fruits stored under low temperature (7 ± 2°C).

Treatment	Total antioxidant activity (mg AEAC 100 ml^{-1})				
	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS
T_1- Polyethylene bags	56.13	56.54	56.90	56.54	55.97
T_2- Polypropylene bags	56.17	56.59	56.95	56.64	56.13
T_3- Xtend®bags	56.07	56.49	56.85	56.46	55.91
T_4- Silver nano bags	56.32	56.64	57.16	56.80	56.26
T_5- Control (unpack)	56.01	56.28	--	--	--
S. Em±	0.103	0.100	0.119	0.126	0.147
CD @ 5%	0.304	0.296	--	--	--

DAS: days after storage; T_1- Polyethylene bags; T_2- Polypropylene bags; T_3- Xtend®bags: T_4- Silver nano bags; T_5- Control(unpack).

B. Sensory qualities

Evaluation of pomegranate fruits was conducted for the sensory qualities *viz*., colour, texture, taste and overall acceptability at 20-day interval. The colour of fruits diminished as storage period got increased. Highest colour score of 9.00 was observed at the time of storing (D0) when the fruits were fresh (Fig. 1). However, after 40 days of storage, maximum (8.50) score for colour was obtained from the fruits packed in Silver nano bags while in the unpacked fruits (control), the score was minimum (5.00). Later, the fruits from the control were discarded after 40 days of storage because of development of scald shrinkage and spoilage. After 100 days of storage, the fruits packed in Silver nano bags had maximum colour (score of 7.50) while the fruits packed in Xtend® bags had minimum colour (6.25 score). Similar results were reported in purple passion fruits (Yumbya *et al*., 2014) and in Pomegrante fruits (Dhineshkumar *et al.*, 2017).

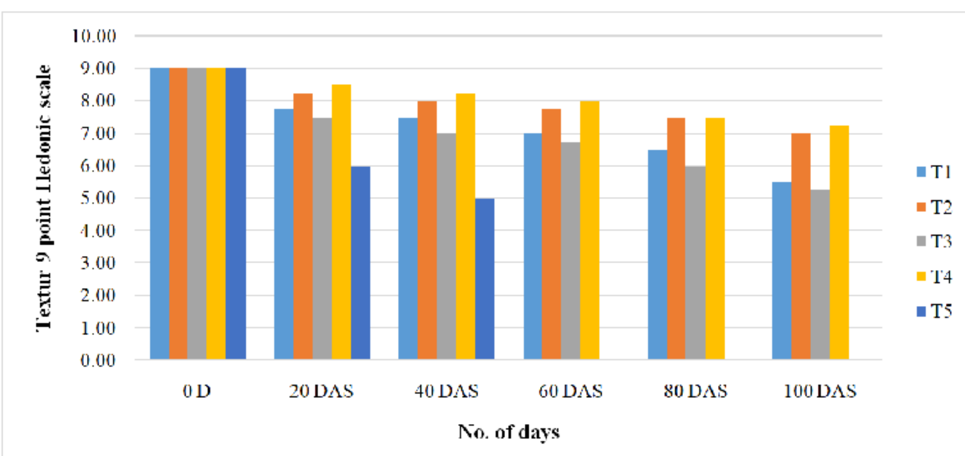


DAS: days after storage

T_1- Polyethylene bags :T_2- Polypropylene bags:T_3- Xtend®bags:T_4- Silver nano bags:T_5- Control(unpack)

Fig. 1. Effect of MAP on colour of pomegranate fruits stored under low temperature (7±2°C).

The data on the texture of the fruits (Fig. 2) revealed that the texture of the fruits decreased with respect to packing materials as well as storage duration. At the time of storage, the texture was found to be maximum (9.00) when fruits were fresh. However, after 40 days of storage the fruits stored in Silver nano bags showed highest score (8.12) for the texture compare to the control fruits where it was least (6.10). After a storage period of 100 days the fruits packed in Silver nano bags had a maximum texture score of 7.25 while it was least (6.10) in the fruits packed in Xtend® bags. The results are in conformity of the work of Dhineshkumar *et al.*, 2017.

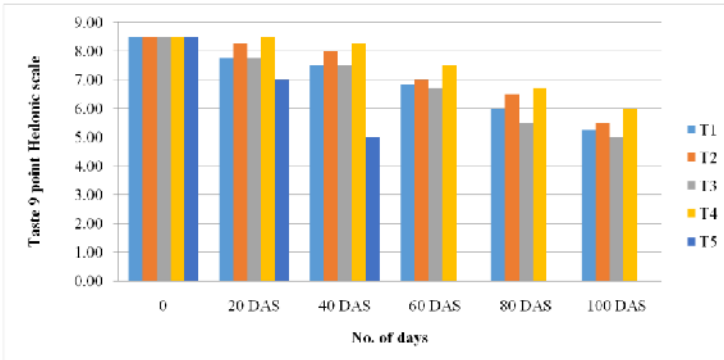


DAS: days after storage

T_1- Polyethylene bags : T_2- Polypropylene bags: T_3- Xtend®bags: T_4- Silver nano bags: T_5- Control(unpack)

Fig. 2. Effect of MAP on texture of pomegranate fruits stored low temperature (7±2°C).

The fruits differed with respect to different packing materials and storage periods with respect to the taste parameter (Fig. 3). The score got reduced as the storage period was extended. The fruits in treatments involving MAP had better tasting range from 7.50 to 8.50 compare to control (5.00) at 40 days of storage. All the unpacked pomegranate fruits in control were discarded after 40 days of storage owing to spoilage issues, while for rest of the treatment the assessment of storage period and remaining sensory parameters was continued till 100 days. At 100 days of storage, highest taste score (6.00) was noticed in the fruits packed in Silver nano bags while the least score (5.00) was noticed in the fruits packed in Xtend® bags. Bayram *et al.*, (2009)) studied the storage performance of pomegranate fruits *cv*. Hicaznar in different packaging materials and found that Strech film wrapped and modified atmosphere packed fruits stored at 6°C and 90 per cent RH recorded highest quality scores up to six months of storage.



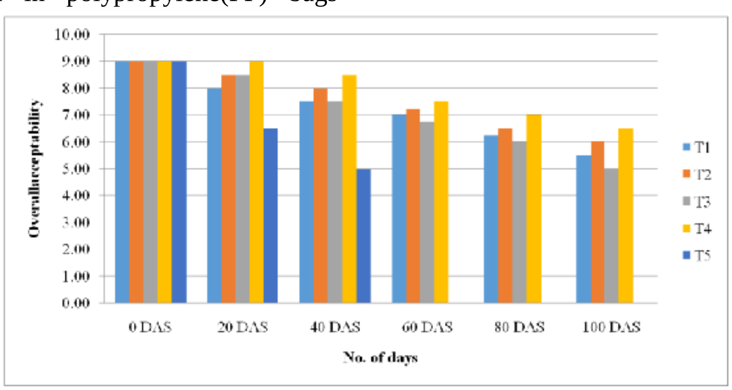
DAS: days after storage

T_1- Polyethylene bags : T_2- Polypropylene bags: T_3- Xtend®bags: T_4- Silver nano bags: T_5- Control (unpack)

Fig. 3. Effect of MAP on taste of pomegranate fruits stored under low temperature (7±2°C).

The data on overall acceptability (Combined qualities of colour, texture and taste with a score from 1 to 9) of the fruits (Fig. 4 & 5) varied among treatments. The score on overall acceptability was 9 when the fruits were fresh. At 40 days of storage, the score was least (5.00) in the unpacked fruits while it was highest (8.50) in the fruits packed in Silver nano bags storage. Similarly, at 100 days of storage the fruits from the Silver nano bags showed highest score (6.50) while it was least (5.00) in the fruits packed in Xtend® bags. The results were in conformity with findings of Dhineshkumar *et al.,* (2017), who reported that sensory score above 6 out of 9 is the limit of acceptance in terms of product attributes such as aril colour, texture, sweetness and juiciness. The sensory evaluation arils packed in polypropylene(PP) bags scored highest point with respect to colour, crispness, sweetness, juiciness and overall acceptance as compared to low density polyethylene (LDPE) and Xtend® film packed arils.

Use of MAP bags is important in maintaining the better visual appearance of pomegranate fruits during storage as they provide greater protection to the fruits by lowering the moisture loss, scald development, variations in acid content, sugar/acid ratio, pH, shrinkage and softening by delaying senescence during storage. Similar results on the importance of MAPs in protecting the various qualities of pomegranate fruits packed in shrink film were obtained by Nanda *et al*. (2001), in mango (Malundo *et al*., 1997) and also in carambola fruits (Rathod *et al*., 2011).



DAS: days after storage

T_1- Polyethylene bags: T_2- Polypropylene bags: T_3- Xtend®bags: T_4- Silver nano bags: T_5- Control (unpack)

Fig. 4. Effect of MAP on overall acceptability of pomegranate fruits stored under low temperature (7 ± 2°C).

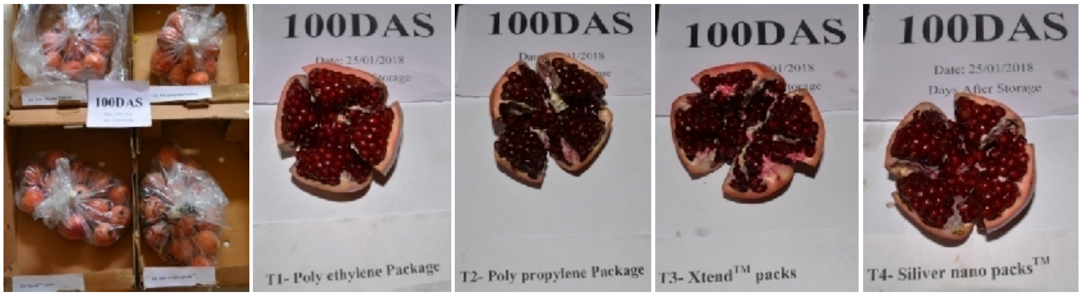


Fig. 5. Effect of MAP on sensory quality of pomegranate fruits at 100 days after storage.

CONCLUSION

Pomegranate fruits packed in different MAP bags and stored in low temperature (7±2°C and relative humidity of 90±5 %) were found to have prolonged storage life, retained chemical properties and had better sensory score. Fruits packed in Silver nano bags were identified best for maintaining quality as they recorded highest sensory score (6.50) after 100 days of storage while unpacked fruits recorded lowest score (5.25) on 40DAS. MAP bags could extend the storage period of pomegranate fruits as long as 100 days and shelf life 4-5 days compared to unpacked fruits which had only 40 days storage life. This extended shelf life of fresh fruits shall be beneficial in long distance transportation or storing pomegranate fruits during surplus and return to the market during lean period to meet the market demands. This helps both growers and consumers in obtaining good quality produce for greater geographical area and to avoid demand supply mismatch.

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Conflict of Interest. None.

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