Application of Modified Atmospheric Packaging to Reduce FoodWaste: A Study with Cooked Rice

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Abstract: This paper deals with a new and innovative idea of active packaging to increase the shelf life of cooked food, to reduce the wastage of food due to unfavourable storage conditions. An innovative method of modified atmospheric packaging "MAP" is introduced in this article. Here we also explore the problem and remedies of wastage, spoliation and damage of cooked food. This paper contains a statistical significance of study of food spoilage in domestic, social & hospitality sector, which are based on available reports. As we know packaging must be safe, efficacious and as per consumer convenience, so we suggest a specially designed food container incorporated with active packaging, which will help to enhance the shelf life of food in order to supply the food to ultimate consumer. Shelf life of cooked food enhancing up to 6 to 12 hours in initial study with cooked rice and cooked vegetables without curry under normal ambient temperature and humidity conditions with specially designed food preservative container. Major scavengers were used for this trial like special oxygen scavengers, activated carbon, natural zeolites and moisture absorbing scavengers. Food preservative container is also having facility to maintain the temperature of cooked food with gas or chilling/hot water circulation system in between two layers of food preservative container.

Index Terms - Modified Atmospheric Packaging, Active Packaging, Food Wastage, Scavengers, Cooked Rice, Shelf Life, Oxygen.

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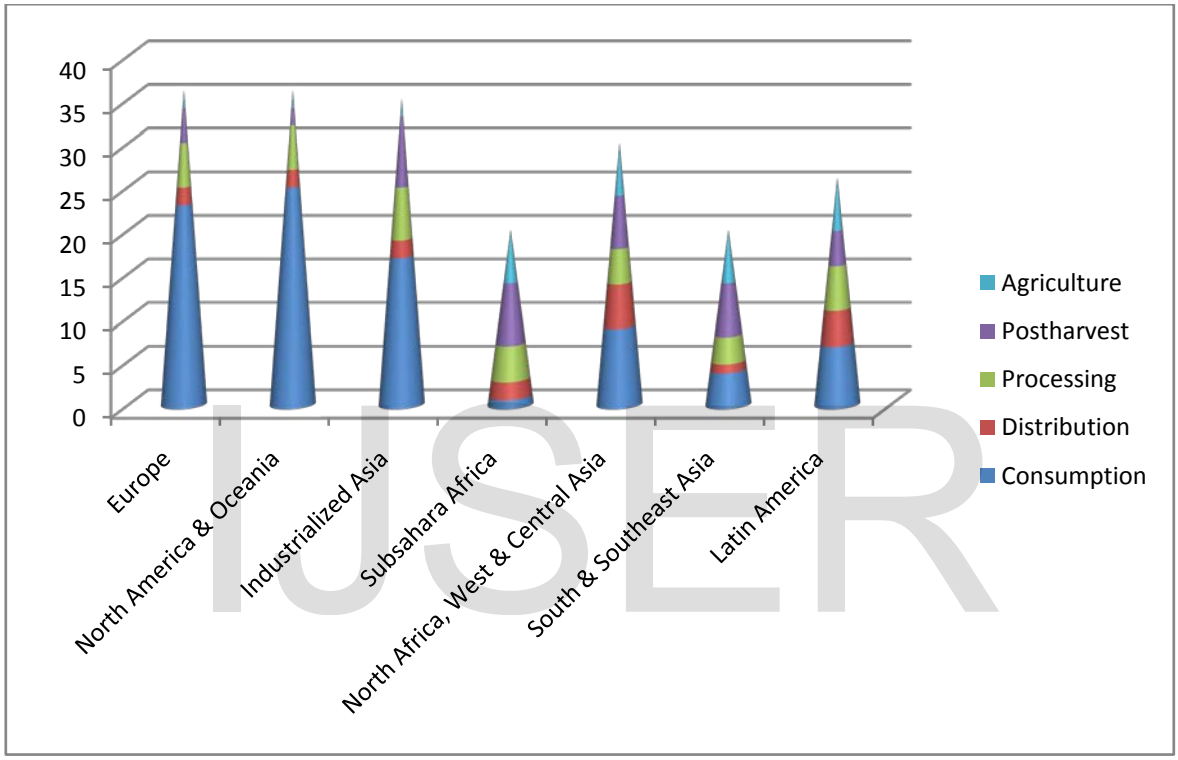
1. INTRODUCTION:

India is a country having feasts and festivals,celebrating social functions all a part of Indian tradition from years. We observe seasonal and harvest festivals and life transitions such as weddings, births, deaths, where food is prepared on large scale on these occasions. In Social gatherings the amount of food wastage seems to be significantly high these days. Most of the social gatherings end with approximately 30%-35% of cooked food wastage. It is estimated that 46% of children below three years are underweight, 79% of children aged 6- 35 months are anaemic, 23 per cent have a low birth weight and 68 out of 1000 die before the age of one year, and 33% of women and 28% of men have a Body Mass Index (BMI) below normal just because they do not have enough food to eat as per study of ministry of consumer affairs.

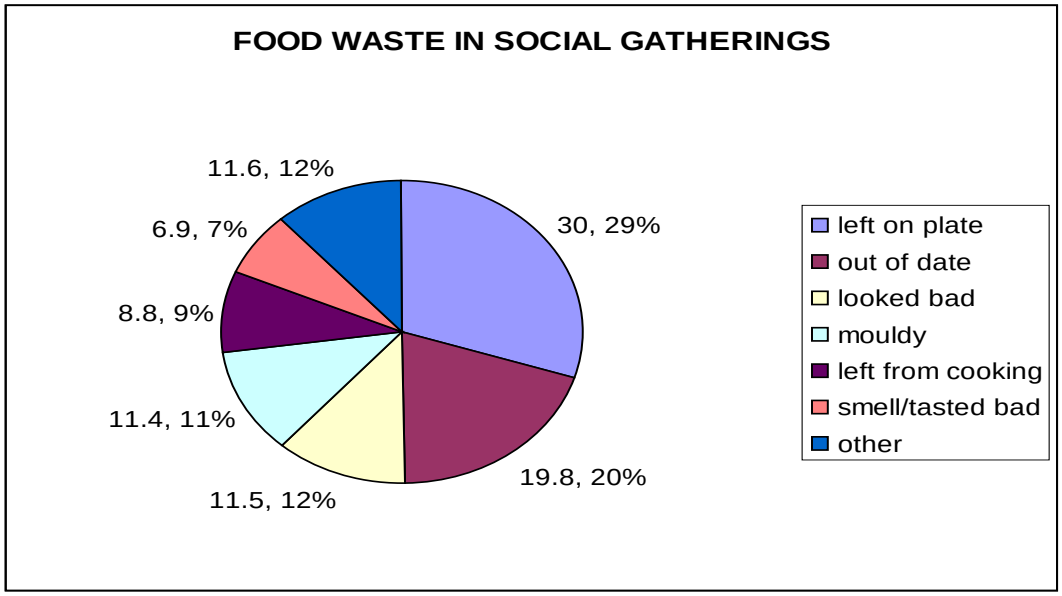
In the past years, in social gatherings limited number of traditional food items were prepared and served by the family members. If some food remained untouched or unserved, it was either consumed by the members of the household themselves or distributed to the fellow villagers, extended families and relatives for consumption. But today among the rich and the rising middle class it is a fashion to hire event managers/wedding planners to organise such gatherings in hotels, restaurants, and farm houses or clubs. Both the

number of dishes and the number of guests on such occasions has increased these days considerably. It is not possible for anyone to taste this wide array of dishes and hence large quantity of food is wasted which either is thrown into the municipal dustbins or at some occasions sold away as feed to the cattle. This is a social crime as millions in the country are malnourished and go to bed without feeding their stomach. Below graph shows the global food waste:



As mentioned in the earlier sections the loss of food at household levelis very high in developed country. But the question is that why so the level offood waste at household is high in developed countries?

Below graph shows the food waste in all types of social gatherings with the description of origin of cooked food waste;



1.1. Definitions of food and its importance:

What is Food: Food is the material consisting essentially of protein, carbohydrate, and fat used in the body of an organism to sustain growth, repair, and vital processes and to furnish energy requirements.

Food waste or food loss is food that is discarded or not consumed.

- **Food loss** is the decrease in quantity or quality of food. Food loss in the production and distribution segments of the food supply chain is mainly a function of the food production and supply system or its institutional and legal framework.
- **Food waste** (which is a component of food loss) is any removal of food from the food supply chain which is or was at some point fit for human consumption, or which has spoiled or expired, mainly caused by economic behaviour, poor stock management or neglect.
- **Leftovers** – this is usually because too much food has been prepared or put on the plate
- **Passed its use by date** – applies mainly to dairy, meat and fish which wasn't used on time
- **Food gone off** – smelt bad, looked bad, tasted bad – this food had a chance but was managed badly
- **Passed its best before date** – this usually impacts things like bread and other staples that waste away in the cupboard.

Food losses also include crops destroyed by drought or pests, and wastes from food

processing such as fruit and vegetable peel. This is largely unavoidable. In contrast, food waste is linked to human action and could potentially be avoided through improved efficiency and planning.

2. FACTORS FOR FOOD SPOILAGE:

Some of the primary food wastagefactors are air, oxygen, moisture, light, temperature, and microbial growth. When two or more of these culprits get together, they can accelerate the spoiling process even further.

When food is exposed to air, microorganisms can land on the food and begin their work of breaking down the food for their own uses. The presence of oxygen enhances the growth of microorganisms, such as moulds and yeasts, and they contributes directly to deterioration of fats, vitamins, flavours, and colours within foods through the work of enzymes.

Some of food spoilage factors discussed below:

2.1- Oxygen

More than any other atmospheric element, oxygen supports the growth of aerobic microorganisms such as fungi and mould. With the growth of these microorganisms, the integrity of a package is drastically compromised. In food products, discoloration takes place, rancidity and putrefaction set in, and the possibility of food poisoning is ever present. With historical documents, art and other artefacts, the presence of oxygen contributes to rapid deterioration, mildew, mould and a wide array of other contaminants. Oxygen absorbers were designed to protect against such problems, when packaged properly (i.e., an appropriately sized oxygen absorber inside of a high oxygen barrier can or bag).

Oxygen is probably the most important gas in this context being used metabolically by both aerobic spoilage microorganisms and plant tissues and taking part in some enzymes reactions in food including the compounds such as vitamins and flavours. For these reasons, in modified atmosphere packaging, oxygen is either excluded or the levels set as low as possible. The exceptions occur where oxygen is needed for fruit and vegetable respiration, colour retention as in the case of red meat or to avoid anaerobic conditions in white fish. In MAP, oxygen levels are normally set as low as possible to reduce oxidative deterioration of food. Oxygen will generally stimulate the growth of aerobic bacteria and can inhibit the growth of strictly anaerobic bacteria, although there is a very wide variation in the sensitivity of anaerobes to oxygen. One of the major functions of O_2 in MAP meats is to maintain myoglobin in its oxygenated form, oxymyoglobin. This is the form responsible for the bright red colour, which most consumers associate with fresh red meat.

2.2. Moisture

Microorganisms need a moist environment to grow in. The water requirements of microorganisms are described in terms of water activity (represented by the symbol a_W), a measure of how much water is present. The water activity of pure water is $a_W = 1.00$. Most foodborne pathogenic bacteria require a_W to be greater than 0.9 for growth and multiplication.

2.3- Temperature

Bacteria exist everywhere in nature. They are in the soil, air, water and the foods we eat every day in our daily life. When bacteria have nutrients (food), moisture, time and encouraging temperatures, they grow rapidly increasing in numbers to the point where some can cause illness. Understanding the critical role of temperature acting in keeping food safe, hygienic and nutritious is critical. If we know the temperature at which food has been handled, we can then answer the question, “Is it safe?”

2.4- pH

The acidity of foods has been used for centuries to preserve foods. Acidity plays a primary role in the preservation of fermented foods and combined with other factors such as heat, water activity, and chemical preservatives acts to prevent food deterioration and spoilage.

The intensity of acidity of a food is expressed by its pH value. The pH of a food is one of several important factors that determine the survival and growth of microorganisms during processing, storage and distribution. Consequently, food processors are interested in determining the pH of foods and in maintaining pH at certain levels to control microbial growth and prevent product deterioration and spoilage.

3- ROLE OF PACKAGING TO REDUCE THE COOKED FOOD WASTE:

Packaging is defined as enclosing food to protect it from tampering or contamination from physical, chemical and biological sources. Packaging maintains the benefits of food processing after the process is complete, enabling foods to travel safely for long distances from their point of origin and still be wholesome at the time of consumption.

Packaging can be divided in following types:

1) Primary packaging: which is in direct contact with the product?
2) Secondary packaging: which is the packaging for the primary packaging?
3) Tertiary packaging: Mostly used for the transportation purpose.

Innovations in packaging were up to now limited mainly to a small number of commodity materials such as barrier materials (new polymers, complex and multilayer materials) with new designs, for marketing

purposes. However, food packaging has no longer just a passive role in protecting and marketing a food product. New concepts of active and intelligent packaging are due to play an increasingly important role by offering numerous and innovative solutions for extending the shelf-life or maintain, improve or monitor food quality and safety.

3.1 Constraint of traditional packaging:

Only wrap the product with shelf life/expiry date is the present trends in Indian packaging market. This packaging system does not represent the current food status even though the expiry date is over. So, the food materials are still consumables or not, it is very chaos. So only active packaging will demonstrate that whether food item can be consume or not.

3.2- Role of active packaging:

In this technique indicators and sensors (easy to use small devices) are used instead of time consuming, expensive quality measurements for improving the shelf life and providing food safety. In smart packaging system indicators give information about product quality by surrounding conditions and head space gases of packages, also indicators can be attached to the package surface or integrate to packages which are improved for determining metabolite residue formed during storage. Temperature, microbial spoilage, package integrity, physical shock, freshness of the packaged product can be controlled.

This new packaging solutions allow improving the economic aspect of packaging materials also. The interest in active and intelligent packaging is successively increasing. This is evidenced by the fact that the global market of active and intelligent packaging for food and beverages coupled with controlled/modified atmosphere packaging (CAP/MAP) increased from $15.5 billion in 2005 to $16.9 billion by the end of 2008 and it should reach $23.6 billion by 2013 with a compound annual growth rate of 6.9%. Introduction of active and intelligent packaging can extend the shelf life of food or improve its organoleptic properties and thus prevent food losses.

4- DESIGN AND DEVELOPMENT OF FOOD PRESERVATIVE CONTAINER:

An innovative method of Modified Atmospheric Packaging “MAP” isrecommended to reduce the wastage of food. As we know packaging must be safe, efficacious and as per consumer convenience, so we suggest a specially designed food container incorporated with active packaging and coating of specially designed polymer, which will help to enhance the shelf life of food in order to supply the cooked food for its ultimate destination.

In this paper, we developed the food container to enhance the shelf life of cooked food. This food preservative container may be foundation for futuristic research in the field of cooked food, raw food and semi-cooked food. Design

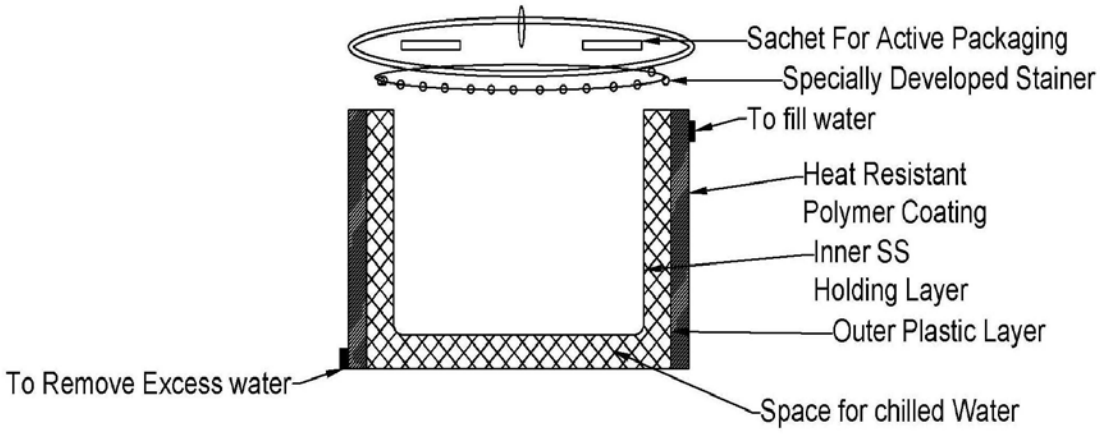
and development of food preservative container is discussed below:

4.1. - Basic concept of design and development:

Present invention is provided a process of making vessel from bottom to top or top to bottom, which covers SS container for holding the cooked food. Outside body is coated with heat resistance polymer on upper most layers and a gap between inner and outer wall for filling the chilled water. Present invention is provided a specially designed cover of vessel incorporated with active packaging. Special oxygen, activated carbon and natural zeolites will be keeping for absorbance. Specially develop strainer will be used for holding different scavengers. This innovative design of food preservative container box is also applied for ordinary patent via application no.:201611007297.

For making vessel: Bottom and Top:

- SS container for holding the cooked food as a primary box
- Outside body of box will be coated with specially designed polymer coating with heat resistance polymer on upper most layer
- Gap between inner and outer wall for filling the chilled water/hot water as per the application of food preservation
- Specially designed cover of vessel incorporated with active packaging. Oxygen and odour scavenger's sachet, which contains iron, activated carbon and natural zeolite, will be keeping for absorbance.
- Specially develop strainer for holding different scavengers.



4.2- Reaction of oxygen scavengers (iron powder oxidation)in container:

The commercially oxygen scavengers available are in form of small sachets containingmetallic reducing agents, such as powder iron oxide, ferrous carbonate and metallicplatinum. The majority of these scavengers are based on the principle of iron oxidation inwater presence. A self-reacting type contains moisture in the sachet and as soon as thesachet is exposed to air, the reaction starts. In moisture dependent types, oxygen scavengingtakes place only after moisture has been taken up from the food. These sachets are stable inopen air before use because they do not react immediately upon exposure to air thereforethey are easy to handle if kept dry. The reactionmechanism of oxygen scavenger based on iron oxidation is very complicated and isdescribed by the following reactions,

$Fe \rightarrow Fe^{2+} + 2e^-$

$½\ O_2 + H_2O + 2e^- \rightarrow 2OH^-$

$Fe^{2+} + 2\ OH^- \rightarrow Fe(OH)_2$

$Fe(OH)^2 + 1/4O_2 + 1/2H_2O \rightarrow Fe\ (OH)^3$

If the oxidation rate of the food product and the oxygenpermeability of the packaging were known, it is possible to calculate the required ironamount to maintain the desirable oxygen level during the storage time. A thumb rule is that 1 g of iron will react with 300 ml of O_2.

5-METHODOLOGY:

The following method was developed for study the shelf life of cooked food with food preservative box implementation of MAP with circulation of chilled water,

5.1. - Theoretical approach of shelf life enhancement in food container box by using MAP:

Cooked food is spoils due to presence of bacteria and bacterial development is due to main five reasons, Temperature, Oxygen, Moisture, Time and Acidity. So we developed new method for cooked food storage to increase the shelf life of food. We will use different type of scavengers to absorb moisture, oxygen, odour and microorganism form the closed loop. All these scavengers will be placed inside of vessel cover, covering with specially designed strainer. So, the absorbance of gases and moisture reaction will be start soon.

When all these factors are controlled then shelf life of cooked food will be increase. We will also use chilled water in between two layer of holding container, so this will reduce the temperature of food. It is also facility of heat resistant polymer coating on outer most surface of food container. So, the food will not be affected by the ambient temperature and will be safe for longer period.

Oxygen scavengers can be used alone or in combination with MAP. Their use alone eliminates the need for MAP machinery and can increase packaging speed. However, it is commercially very common to remove most of the atmospheric oxygen by MAP and then use a relatively small and inexpensive scavenger to mop up the residual oxygen remaining within the food package. Non-metallic oxygen scavengers have also been developed to alleviate the potential for metallic taints being imparted to food products.

In this study, cooked rice isused for the study of MAP and without MAPis taken as a test sample for identifying the sensory attributes of cooked rice shelf life with new design and development of MAP to enhance the shelf life. Test method followed by;

a) **Cooking:**About 2 kg of raw rice were washed with tap water properly and followed by rinsing with drinking RO water. Drinking RO water also added for cooking the raw rice approximately 45 minutes on hot plate.

b) **Cooling:** Cooked rice was divided into 8 parts equally for further testing of shelf life. It is cooled at room temperature, under fan air, in refrigerator for cooling time study as well as uniform cooling. It is found that in under fan air cooling was most uniform and good for reducing the risk of microbial contaminations.

c) **Sample preparation by using MAP**: Cooked and cooled rice are transferred in specially designed food preservative container for study the shelf life for sensory evaluation. Total four samples are made for MAP study. Along with this four others test samples kept for study in normal food caring box. Totally 8 no's of samples kept at room temperature protected from direct sunlight.

d) **Time duration for test samples:** Study was conducted every 6 hours for sensory attributes with ten numbers of men and women for colour, texture, taste, smell and overall acceptability of cooked food.

6-RESULT AND DISCUSSION:

Performance of design and development was measured as per sensory evaluation but it is also proposed future research for proximate composition analysis like moisture, crude protein, crude fat, calories value as well as Total viable count (TVC) also.

6.1 -Cooling of cooked rice:

Several methods were examined for uniform cooling of cooked rice like room temperature, in normal but in fan air and refrigeration. This test conducted with thick layer (4cm) of rice in plate and kept in respective place for uniform cooling. It was found that uniform cooling was more in the samples, which were kept in normal condition under fan air. So, it may reduce the risk of bacterial growth due to uniform temperature within the entire surface area of cooked rice. Finally all these rice were used for trial conducted for modified atmospheric packaging containing oxygen scavengers and active carbon scavengers with

circulation of chilled water. Food preservative container was also having the outermost layer of specially coating with heat resistant polymer. Study is also conducted upon cooked rice under normal condition in fan air with normal food preservative container without MAP.

6.2 Sensory evaluation for shelf life enhancement:

After storage of every six hours of interval, samples were collected up to maximum of 24 hours (total 4 attempts). Total 32 samples were collected and tested for its primary qualification of acceptance for taste the samples. This acceptance was based on the smell and texture of the cooked rice for both the method testing. Based on the feedback of reviewer, first and second attempt (6-12 hours) of samples passed for next cycle of sensory evaluation of cooked rice. Third and fourth attempt (18-24 hours) of samples not recommended for next cycle of sensory evaluation due to unpleasant smell.

This method was also applied to cooked vegetables for the study of shelf life enhancement. Rating of reviewer for cooked vegetables did not qualify after first attempt (6 hours) of storage. It may be due to seasonal variation of atmosphere and different climatic condition of raw vegetables. Due to this reason, cooked vegetables were not included for the present study.

For testing the sensory attributes, cooked rice kept in both type of food preservative box were tasted by group of peoples for the parameters of smell, colour, texture, overall acceptability and taste. Total 8 samples were made for sensory attributes trial and tasted by ten persons in age group of 22-55 years with combination of men and women.Except sample Test sample TS-4 and TS-8, all the test samples were heated in electric oven for 1 minute before serve to reviewer.

For trial of sensory attributes samples were classified as test sample TS-1 to TS-8, where TS-1 is Cooked and cooled at room temperature, TS-2 is Cooked and cooled under fan air, TS-3 is Cooked and cooled in refrigerator and TS-4 is Cooked and cooled under fan air but not heated and kept in food preservative box with MAP. Test samples from TS-5 to TS-8 were kept in normal container without MAP and classified as TS-5 is Cooked and cooled at room temperature, TS-6 is Cooked and cooled under fan air, TS-7 is Cooked and cooled in refrigerator and TS-8 is Cooked and cooled under fan air but not heated. Reviewer were given the rating from 1-9 in sensory attributes from, where 1 rating means ‘dislike extremely’ and rating 9 means ‘like extremely’ as per Hedonic Scale. Hedonic test was conducted for all eight test samples and the mean of reviewer feedback tabulated in table 1and Table 2:

Table-1: Average rating of reviewer for cooked rice with the use of MAP:

Sensory Attributes Trail for Cooked Rice with Modified Atmospheric Packaging					
Types of Samples	**Sensory Attributes**				
	Smell	**Colour**	**Texture**	**Overall Acceptability**	**Taste**
Cooked and cooled at room temperature (TS-1)	5.2	6.3	6.1	5.5	5.4
Cooked and cooled under fan air (TS-2)	6.1	6.2	7.1	7.2	6.2
Cooked and cooled in refrigerator (TS-3)	5.3	5.5	5.5	5.8	5.5
Cooked and cooled under fan air but not heated (TS-4)	5.5	5.7	4.9	5.6	5.4

Table-2: Average rating of reviewer for cooked rice without the use of MAP:

Sensory Attributes Trail for Cooked Rice without Modified Atmospheric Packaging					
Types of Samples	**Sensory Attributes**				
	Smell	**Colour**	**Texture**	**Overall Acceptability**	**Taste**
Cooked and cooled at room temperature (TS-5)	4.1	5.2	4.2	5.1	4.3
Cooked and cooled under fan air (TS-6)	4.3	5.3	4.9	5.3	4.1
Cooked and cooled in refrigerator (TS-7)	5.2	5.1	4.5	3.3	3.8

Cooked and cooled under fan air but not heated (TS-8)	3.9	5.3	3.7	4.6	2.7

Table 1 and 2 shows that average of test sample with the use of MAP is higher score (5.5) rather than without MAP score (4.4). So, it is indicating that test samples were more about 'Like Slightly' but test samples for cooked rice without MAP were equal to 'Dislike Slightly'. It was also observed that rating was high (Like Slightly) for the rice, which was kept under fan air.

In terms of colour test analysis from table 1 and 2, it appears from all the test samples were equally acceptable and ranked with MAP was 5.9 almost 'Like slightly' and without MAP it was 5.2 almost equal to 'Neither like nor Dislike'. It was also observed that rating was 6.2 just more than 'Like Slightly' for the rice, which was kept under fan air.

With the outcome of table 1 and 2 test result is observed that in terms of Texture and Overall acceptability were in between 5.9 and 6.0 respectively. It shows that texture and overall acceptability was 'Like Slightly' for the cooked rice, which were kept with MAP. It is also noticed thathigh rating was highest in cooked rice which were cooled under fan air, which were highest among all the test sample results. For cooked rice kept without use of MAP is rated 4.3 for texture and 4.6 for overall acceptability. Test results can be ranked as 'Dislike slightly' as well as 'Neither like nor Dislike'.

For the test analysis of taste performance of cooked rice with the use of MAP, it was 5.6 and just near to ' Like slightly'. Test sample TS-2 achieved the overall highest rating among all 8 test samples. TS-2 sample was kept in cooling under direct fan air and studied further with the use of MAP. Rating for cooked rice without MAP ranked 3.7 as very near to 'Dislike Slightly' and also got minimum score (2.7) for the cooked rice kept under fan air but not heated.

7-CONCLUSION:

From all the result of test samples, it is clearly indicated that cooked rice, which was kept with the use of specially designed food preservative container with modified atmospheric packaging, was able to enhance the shelf life of cooked rice up to 6-12 hours of its cooked time. The test sample result of cooked rice without MAP in normal box is failed to overall acceptance from the reviewer and ranked as 'Dislike slightly'.

This study is milestone for the further research in the field of cooked food spoilage globally. Current study is also indicating that modified atmospheric packaging have the potential of save the mass food and can be better solution

rather than traditional way of cooked food preservation technique.

This study would be beneficial for hotels, event management groups, institutional, daily working passengers as well as government scheme like right for food, mid-day meal for school etc.

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