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DEVELOPMENT OF SHELF STABLE INTERMEDIATE MOISTURE CAULIFLOWER BRASSICA OLERACEA, VAR, BOTRYTIS CABBAGE BRASSICA OLERACEA, VAR, CAPITATA USING RADIATION AS HURDLE TECHNOLOGY

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Abstract— Processing conditions were established for developing shelf stable 'intermediate moisture (IM) cabbage and cauliflower. The new protocols were based on the hurdle technology (HT) - a mild heat treatment, addition of **1% Potassium meta bi sulphite as antimicrobial agent, partial dehydration** to lower water activity (aw) using **two methods - Infrared drying (IR) / Tray drying (TD). The IM vegetables prepared were packed in 400 gauge polyethylene covers and treated with low doses of gamma radiation as major hurdle technology and observed for shelf life stability at ambient conditions (30oC and 65% RH). The physical, chemical and pathological stability was monitored during storage.** Infra red dried (IR) vegetables **treated with gamma radiation at 0.75-1.0 kGy yielded a product with improved rehydration potential, appearance and maximum nutrient retention up to 43.1%-44.6 % of vitamin C with maximum shelf life of 5 to 7 months. No significant changes were noticed in scores for colour, taste, flavor, texture and overall acceptability during storage period. The product was microbiologically safe throughout the study.Among the four treatments studied, infrared dried with radiation dose of 0.75 kGy and1.0 kGy was found to be best in obtaining high quality IM products with optimum sensory, microbial nutritional quality and storability.**

INDEX TERMS- ***S*****helf stable, Intermediate moisture, hurdle technology, Infrared drying, gamma radiation**

1. Introduction

Cauliflower (Brassica oleracea, var, botrytis) and cabbage (Brassica oleracea var. capitata) Subspecies of Brassica oleracea, belong to Cruciferous family Cruciferous vegetables, including subspecies of B. oleracea, are relatively abundant sources of antioxidants with potential anti carcinogenic activity Cauliflower and cabbage are important cole crop (crop near to the soil) of India. The estimated post harvest loss per hectare in India is about 49% (Sehgal, 1999). Cauliflower prices become very low during main season and sometimes farmers have to pay to throw away their produces because of higher perishable nature of the produce. Fresh cauliflower has 92 to 94% water and it can be stored for 2 to 4 weeks at 0 °C (Mudgal and Pandey, 2007).

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Processing of cauliflower can be an alternate for extending the shelf life.The most serious constraint for shelf-life enhancement is the activity of micro-organisms. Cauliflower is low in fat, low in carbohydrates but high in dietary fiber, folate, water, and vitamin C, possessing a high nutritional density. Cauliflower contains several phytochemicals, common in the cabbage family that may be beneficial to human health. Sulforaphane, a compound released when cauliflower is chopped or chewed, may protect against cancer. Other glucosinolates, Carotenoids (42). Indole-3-carbinol, a chemical that enhances DNA repair (43, 44) and acts as an estrogen antagonist (45) slowing the growth of cancer cells. A high intake of Cruciferousvegetables has been associated with reduced risk of aggressive prostate cancer there is, therefore, a growing and urgent need for simple, inexpensive processes that would offer a way to save these highly perishable commodities from spoilage.

Conventional dehydration and canning processes, have many drawbacks with rigid structures which need rehydration for prolonged periods and generally have texture and flavor inferior to the fresh materials, it is unsuitable due to shrinkage to toughness caused by slow prolonged drying (Jayaraman, 1988). Canned products on the other hand, suffer from the disadvantages of bulk, weight, overcooked texture and flavor, high cost (due to high energy input, cost of tinplate and capital investment) and dependence for safety or wholesomeness on the integrity of the container. One of the alternatives to dried vegetables is the intermediate moisture (IM) foods. IMF foods are easy to prepare and store without refrigeration. They are energy efficient and relatively cheap. They are not readily subject to spoilage, even if packages have been damaged prior to opening, as with thermo stabilized foods, because of low aw. This is a plus for many developing countries, especially those in tropical climates with inadequate infrastructure for processing and storage, and offers marketing advantages for consumers all over the world (Gustavo et al., 2003).

Development of intermediate moisture foods is based on an increased scientific understanding of the chemical reactions involved in traditional food preservation methods (Purvi et al., 2003). A controlled multi-hurdle could be applied without affecting the sensory and nutritional properties. Over the last decade, use of this approach has led to important developments of innovative technologies for obtaining shelf-stable "intermediate moisture products" (IMP) storable for 3-8 months without refrigeration. These new technologies are based on a combination of inhibiting factors. Among the newer techniques for preservation of such products, treatment with ionizing radiation is one of the most promising. The non residual feature of ionizing radiation is an important advantage making it an effective alternative to chemical treatments. Gamma irradiation has long been employed for decontamination and/or sterilization of dehydrated vegetables (Sharma et al., 2009). However, use of radiation technology to minimize or avoid the use of other hurdles has been very limited. Hence the study was under taken to study the impact of combination of infrared drying and radiation technology in processing Intermediate product and increasing shelf life.

2. Materials and methods

Vegetables were procured from local market, cleaned and trimmed manually.

Cabbage was chopped manually to about 2 cm long strips on a cutting board. The Cauliflower florets were separated and cut to thickness of about 2cm. Several trials with different variations were carried out to standardize the optimum pretreatment, drying conditions, packaging material and radiation dose to improve and retain the product quality. The standardized protocols were used for preparation of IM Cauliflower and cabbage. The preparation of IM Cauliflower and cabbage is presented in flow chart (Figure.1.)

The following treatments were designed to ascertain the effect of shelf stability with optimal organoleptic quality.

Treatment 1 Tray dried (TD).
Treatment 2 Tray dried and radiated (TDR).
Treatment 3 Infra red dried (IR).
Treatment 4 Infra red dried and radiated (IRR).

Standardized IM Cauliflower and cabbage were aliquoted into separate packages and stored under ambient conditions. At predetermined interval of storage period (i.e., 0, 30, 60, 90, 120, 150 and 180 days) the IM products in triplicate are removed and analyzed for physical, nutritional, microbiological and sensory acceptability.

2.1. Physical properties

2.1.1. Color Measurement

Hunter lab colour spectrometer was used for colour estimation. The most common technique to assess the colour is by colorimetry. There are several colour scales in which the surface colour can be represented. The 3-dimensional scale L*, a* and b* is used where L* is the lightness coefficient, ranging from 0 (black) to 100 (white) on a vertical axis. The a* is purple-red (positive a* value) and blue-green (negative a* value) on a horizontal axis. A second horizontal axis is b* that represents yellow (positive b* value) or blue (negative b* value) colour (McGuire, 1992).

2.1.2. Physiological loss of weight (PLW)

Physiological loss of weight was estimated by recording initial and subsequent weights during storage at regular intervals. (Ranganna, 1986).

2.1.3. Rehydration ratio

Rehydration ratio was recorded as ratio of the weight of dehydrated sample to the weight of rehydrated sample and per cent of loss in weight was also computed (Ranganna, 1986).

2.1.4. Chemical analysis

Moisture was estimated by AOAC, 1990. Vitamin C and acidity were estimated by titration method (Ranganna, 1986).

2.1.5. Microbial analysis

For estimating viable bacterial, yeast and mould count dilution plate method was followed. For bacterial estimation, plate count agar was used and for yeast and mould potato dextrose agar was used (Krishnakumar et al., 2006).

2.1.6. Sensory evaluation

The organoleptic scoring was done by a panel of 10 members in the sensory evaluation laboratory using a score card developed for IM cabbage and cauliflower evaluation purpose. A five point hedonic scale was used to evaluate (Peryam, 1957) the results were expressed as mean scores by taking average of all the replicates.

2.1.7. Statistical Analysis

All the experiments were repeated three times and data obtained was statistically analyzed using Analysis of Variance ANOVA (Snecdor et al., 1983) two factor with replications to assess the significant difference at 0.05 % and 0.01% level using AGRES software. The effects of treatments between and within were compared. Once the product was spoilt that treatment was eliminated from analysis and only other three treatments were considered for two factor analysis.

3. Results and Discussion

3.1. Standerdization of IM vegetables processing

Pre-treatment is common in most processing operation to improve product quality or process efficiency (Jha.S.N.et al., 1996). Optimum pre-treatment for cabbage and cauliflower was found to be the blanching in one percent potassium meta bi sulphite. Blanching gave the best results when kept for rehydration as it regained its original characters like color, texture, appearance etc Additionally, blanching improves the color of products by preventing discoloration and improving brightness, thereby making the product more attractive for consumption (Brewer et al., 1995) and (Kilara et al., 1984). It is used to preserve foods without significant changes to their quality (Azam-Ali et al., 2003).

Pre treated cabbage and cauliflower were dried in the Tray drier (TD) at 80ºC and in Infra red drier (IR) at 60ºC till the desired moisture level (~ 30 %) attained Heating to appropriate temperatures for appropriate times is, essential for preserving (Azam-Ali et al., 2003). The total drying time varied with drying conditions. Tray drier consumed longer time to attain IM moisture level than infrared drier. The shortest drying time was observed with infrared drying. Similar advantages like reduction in drying time, providing uniform temperature in the product while drying, and better-quality finished products, with the infrared drier have been reported by (Dostie et al., 1989),(Navari et al., 1992),(Sakai and Hanzawa, 1994), (Mongpreneet et al., 2002). Low temperature drying with infrared lamps has been shown to be a potential useful method for preserving heat sensitive natural products since it is gentle and shortens the processing time significantly (Paakkonen et al.,1999).

A study by Sagar and Kumar, (2006) reported that 200 gauge HDPE is most suitable for retention of better quality in respect to colour, flavour, texture and overall quality for 4 months at room temperature and 6 months at low temperature (7.0±20C) followed by 400 gauge LDPE. Most of the studies reported, intermediate moisture fruits and vegetables packed in an oxygen free atmosphere keep an excellent condition for substantial periods, in some cases over two years at ambient temperature.

Among different doses of radiation treatments, 0.75 kGy dosage for cauliflower and 1.0 kGy for cabbage were recorded lower PLW and higher sensory acceptability compared to other doses. Hence considering all parameters, dosage of 0.75 and 1.0 kGy were considered best for IM cauliflower and IM cabbage respectively. The standardized protocols are presented in Table. 1.

3.2. Shelf life

IRR showed high product quality and improved food safety and maintained optimum sensory, microbial and nutritional quality. The hurdle efficiencies were in the following order TD> IR> TDR>IRR.Among the treatments studied, the IM cauliflower and cabbage dried in infrared drier and packed in 400 gauge polyethylene bags with Irradiation dose of 0.75 to 1.0 kGy was found to be best. The shelf life of infrared radiated IM cauliflower and cabbage were increased 5 to 7 months at ambient temperature. Whereas the shelf life of the non irradiated was limited to two to three months. Shelf life extension with low doses of irradiation was reported earlier also. (Paul et al., 1990). Hurdle processing extended the shelf life to more than 6 months in terms of microbial, organoleptic safety of the product. Table 2. shows the effect of drying and radiation on shelf life and physical quality of IM cauliflower and cabbage stored at ambient temperature. Cabbage showed (7months) higher stability at ambient temperature followed by cauliflower it may be due to variation in sample size because IR efficiency is associated with sample depth as reported by (Sawai and others 1995) that an increase in the sample depth slows down the bulk temperature increase of the food sample. Vegetable size should be restricted to less than 5mm in thickness to improve drying efficiency (Sakai and Hanzawa 1994). Duration of storage clearly indicated that infrared dried with radiated was best among all the treatments by enhancing shelf life with minimal loss of moisture.

3.3.Physiological loss of weight (PLW):

There was significant change in treatments, storage period and interactions Maximum PLW was found in TDR (7%) and minimum in IRR (1.88%) Among the four treatments studied, infrared drying with radiation dose showed minimal loss of weight at ambient temperature.

3.4. Rehydration Ratio (RR)

Infrared dried radiated gave the best results when kept for rehydration. It has regained its original characters like color, texture, appearance etc. Maximum RR was observed in IRR treatment 8.8 and 8.5 for IM cauliflower and IM cabbage respectively. There was significant change in RR among different treatments with storage period. Interaction effects between treatment and storage period were significant. TDR showed lowest rehydration (52.63%) This behaviour might be due to the fact that prolong heating coagulates the protoplasmic protein and destroys the osmotic properties of cell membrane, resulting less swelling of dehydrated material (Vega-Galvez et al., 2008). IRR showed 77.51% to 85.23% of rehydration capacity even after 5 to7 months of storage at ambient temperature. IRR products rehydrated very rapidly, with excellent flavor, texture and aroma. Hence IRR was found to be best treatment for IM cabbage and cauliflower.

3.5. Color values:

The lightness (L*) values of the IM Cabbage and cauliflower samples treated with tray drier were seen to decrease (darker) with increase in the storage period. The results showed difference in color values after heating and during rehydration .On ZERO day, L*, a*,b* values were more nearer to fresh in infra dried samples than tray dried samples. Blanching process favored the retention of vegetable color. The TD, TDR IM cauliflower turned darker in color within one month. This was apparent from the lower L*-value (lightness), greater a*-value (greenness) and higher b-value compared with the 0 day samples. The decrease in the L*-value followed by increase in the a*-value after one month storage was due to an increase in darkness intensity. The IR, IRR retained natural color till the end of storage period.

3.6. Acidity

There was significant change in acidity among different treatments and during storage. During storage maximum acidity was observed in tray dried samples (1.536 %) and minimum in Infrared-radiated samples (0.64%) may be due to fermentation in tray dried products.

3.7. Ascorbic acid

Ascorbic content was used as a nutrition quality indicator since vitamin C is more sensitive
to heat, oxygen and light. Therefore, the retention of vitamin C was used as one indicator of IM vegetables quality. After processing retention of vitamin C was highest in (75.3%) infrared IM products than tray dried (48.7%). Table .3 shows the effect of drying and radiation on nutritional and microbial quality of IM cauliflower and IM cabbage stored at ambient temperature.Vitamin C is heat sensitive and prolonged exposure to higher temperature destroys it. Optimum temperature for maximum vitamin C retention was observed to be 60°C. Kaur and Singh (1981) also reported the similar findings. It has been reported that Infrared (IR) heating provides significant advantage over conventional heating, including lower losses of vitamin C (Niibori, 1988). It has also been suggested that vitamin C content in dried products would decrease significantly with drying temperature and drying rate Some researches also reported that the negative effect of temperature on vitamin C (Lin et al., 1998 and Yen et al., 2008). Significant decrease was recorded in ascorbic acid on storage. These observations were in conformity with the findings of Harsmirat and Dhawan (2003) Jain and Nema(2007) where in they reported a decrease in ascorbic acid content on storage.
Maximum retention of ascorbic acid was observed in IR and IRR (43.1% and 39.2 %) and least in TDR during storage period. The decrease in vitamin C content can be attributed to its sensitivity to light, temperature and oxidation. Ascorbic acid is highly sensitive to oxidation and oxidizes very quickly in the presence of oxygen, it might have been oxidized to dehydro ascorbic acid. This could be the reason for the reduction in the ascorbic acid content during storage. Some of the studies revealed that Irradiation can reduce ascorbic acid (vitamin C) in some vegetables, but the decrease is generally insignificant, (Fan and Sokorai, 2002).
Ahn et al., (2005) found that gamma irradiation at 1 kGy or above significantly reduced the phenolic contents in the cut Chinese cabbage. Reduction of phenolic compounds in the foods due to irradiation has been also reported by Villavicencio et al. (2000). It is evident that irradiation reduced PPO activity and the reduction was proportional with irradiation dose PPO activity of irradiated samples was lower than that of non-irradiated ones up to 14 days. Thus the enzymatic browning and changes in the color could be avoided and quality of IM vegetables would be maintained.

3.8. Microbial count

On zero day non-irradiated and radiated samples doesn't contained any viable count of microbial population. Samples dried in infrared and irradiated with 0.75 -1.0 kGy dose found to be best with least microbial growth during storage period. Nonirradiated showed a significant increase in yeast and mold during storage when compared to radiated samples. The lower count of bacteria, yeast and mould in radiated samples may be due to DNA damage of bacteria on exposure to radiations leading to cell death (Brennan, 2006). Krattak et al., (2005) reported that with minimal dose 0.19kGy and 0.17 kGy of irradiation eliminated Escherichia coli and 0.25 and 0.29 kGy Salmonella Paratyphi in cucumber and cabbage, respectively.
TDN was highly populated than IRN may be due to microbial inactivation as infrared heating source produces more energy. Hamanaka and others (2000) Sawai and others (2003) reported shorter treatment time was enough to inactivate pathogens E. Coli population, bacteria with minimal changes in food quality. No Coli forms were observed in any sample throughout the storage period, indicating that the product was stable with respect to bacteria, yeast and mold growth.

3.9. Organoleptic qualities

The color, aroma, taste and texture are the important characteristics for acceptability of any product and also good indicators of the adverse physico-chemical changes during storage. On ZERO day, maximum scores were found in IR and IRR. Scores decreased with increase in storage period (Table.4.). Minimum decrease was observed in IR and maximum in TDR In general, browning increased with increase in storage period, irrespective of driers. Maximum browning was observed in TDR, TD samples than in IR, IRR samples. Acceptability of IM cauliflower and cabbage of IRR was found to be good up to five to seven months at ambient temperature. Among the four treatments studied, infrared dried with radiation dose 0.75 kGy and1.0 kGy was found to be best in terms of taste, flavor, texture, color and overall acceptability at ambient temperature.

4. Conclusion

It can be concluded from the study that IM cauliflower and cabbage can be stored up to 5 to 7 months at ambient temperature by a different combination of hurdles of reduction in aw to about 0.6, Infra red drying, radiation processing and 400 gauge LDPE bags without having much affect on its physico-chemical, nutritional and organoleptic properties. Reductions in aw, Gamma irradiation suppressed the growth of microorganisms and improved the shelf stability where as the shelf life of the non irradiated control was limited to two to four months. Minimum drying time of IR lowered the browning, and attributed to maximum retention of nutritional, sensorial quality and rehydration ratio. The combinations of hurdles used were more effective than use of a single preservative in large amounts which may not provide the same effect.

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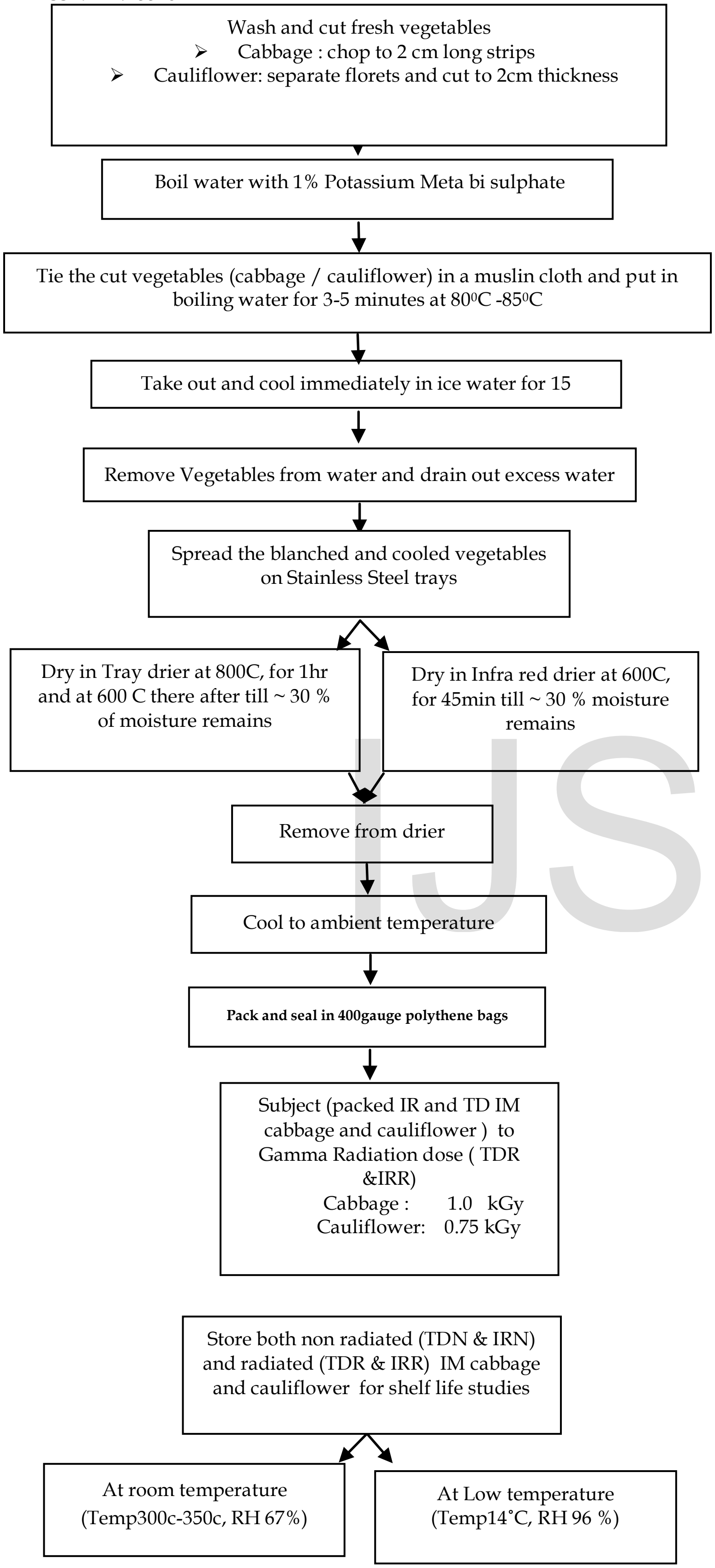

FIG. 1 Preparation of IM Cauliflower and cabbage

Table .1. Standardized protocols

vegetables	Pretreatment	Optimum dose kGy	Packing material	Mode of drying: Infra red		Mode of drying: Tray dried		Percent of moisture
				Drying time (h:m)	Temp ⁰c	Drying time (h:m)	Temp ⁰c	
Cauliflower	Blanchingin 1%KMS	0.75	400 gauge poly ethelyne covers	2.45	60⁰C	5:30	80⁰C	27%
Cabbage	Blanchingin 1%KMS	1.0	400 gauge poly ethelyne covers	2.00	60⁰C	4.00	80⁰C	30%

Table .2. Effect of drying and radiation on shelf life and physical quality of IM cauliflower and cabbage stored at ambient temperature

Para meters	Before: Cauliflower				Before: Cabbage				After storage: Cauliflower				After storage: Cabbage			
	TD	TD R	IR	IRR	TD	TD R	IR	IRR	TD	TDR	IR	IRR	TD	TDR	IR	IRR
Shelf life									2m	3m	4m	5m	3m	5m	4m	7m
Moisture content (%)	24.3	24.3	23.7	23.7	27.6	27.6	26.7	26.7	21.8 (10.1)	21.5 (11.4)	23 (3)	23 (2.9)	25.3(8.3)	23.0 (16.5)	25.6 (4.1)	23.5 (12)
PLW									6.3	7.0	1.5	1.9	4.1	3.2	1.3	1.2
RR	7.2	7.5	8.0	8.8	8. 5	8. 5	8.5	8.5	5.5 (76.7)	6.5 (78.7)	6.1 (81.3)	7.2 (85.2)	5.3 62.7)	4.5 (52.6)	6.4 (75.3)	6.6 (77.5)
Colour Values																
L*	38.1	38.1	40.1	40.1	74.1	74.1	74.1	74.1	16.6	11.4	18.4	15.4	69.1	69.2	70.9	69.3
a*	8.8	8.8	5.3	5.3	2.6	2.6	2.6	2.6	6.4	6.0	6.8	6.2	3.9	4.6	3.8	4.2
b*	28.5	28.5	25.1	25.1	21.3	21.3	21.3	21.3	8.4	8.1	9.0	8.0	24.4	23.7	23.0	24.2

Note: Fig in parenthesis indicate Per cent change over initial value
TBC- Total bacterial count,TMC- Total Microbial count
TD-Tray dried, TDR- Tray dried radiated, IR-Infra red dried, IRR-Infra red dried radiated.

Table .3. Effect of drying and radiation on nutritional and microbial quality of IM cauliflower and cabbage stored at ambient temperature

	On Zero day								At the end of shelf life							
Parameters	**Cauliflower**				**Cabbage**				**Cauli flower**				**Cabbage**			
Nutrients	**TD**	**TDR**	**IR**	**IRR**	**TD**	**TD R**	**IR**	**IRR**	**TD 2m**	**TDR 3m**	**IR 4m**	**IRR 5m**	**TD 3m**	**TDR 5m**	**IR 4m**	**IRR 7m**
Acidity	0.896	0.896	1.15	0.77	0.96	0.96	0.96	0.96	1.5	1.54	0.77	0.64	1.42	1.52	0.59	0.56
Vit 'C' (mg/100g)	38	38	58.7	58.7	32.0	32.0	35.0	35.0	11.4 (30)	5.7 (13.2)	25.3 (43.1)	23.0 (39.2)	19.5 (61.0)	10.1 (31.59)	20.1 (57)	13.2 (37.7)
TBC (log cfu/gm)	nvc	nvc	nvc	nvc	nvc	nvc	nvc	nvc	2.1	1.7	1.72	0.58	2.53	2.51	0.77	1.95
TMC log cfu/gm)	nvc	nvc	nvc	nvc	nvc	nvc	nvc	nvc	2.08	1.9	1.9	0.77	2.49	2.45	1.90	1.90

Note: Fig in parenthesis indicate Per cent change over initial value
TBC- Total bacterial count,TMC- Total Microbial count
TD-Tray dried, TDR- Tray dried radiated, IR-Infra red dried, IRR-Infra red dried radiated.

Table .4 Effect of drying and radiation on Sensory evaluation of IM cauliflower and cabbage stored at ambient temperature

Parameters	**On Zero day**								**At the end of shelf life**							
	Cauliflower				**Cabbage**				**Cauliflower**				**Cabbage**			
Sensory score	**TD**	**TDR**	**IR**	**IRR**	**TD**	**TDR**	**IR**	**IRR**	**TD 2m**	**TDR 3m**	**IR 4m**	**IRR 5m**	**TD 3m**	**TDR 5m**	**IR 4m**	**IRR 7m**
Taste	4.8±0.5	4.6±0.2	5.0±0.2	4.9±0.2	4.9±0.2	4.9±0.5	4.8±0.2	4.8±0.3	2.0±0.2	1.8±0.3	2.1±0.2	2.0±0.2	2.9±0.3	2.0±0.2	3.1±0.2	3.0±0.1
Flavour	4.7±0.3	4.7±0.3	4.6±0.1	4.6±0.3	4.7±0.3	4.7±0.6	4.6±0.3	4.6±0.2	1.6±0.5	1.2±0.6	3.0±0.3	2.0±0.1	2.6±0.5	2.0±0.3	3.6±0.1	2.5±0.2
Texture	4.0±0.2	4.0±0.4	5.0±0.2	4.7±0.2	4.5±0.1	4.5±0.6	4.6±0.1	4.6±0.1	1.7±0.6	2.1±0.5	3.3±0.2	2.8±0.2	1.4±0.4	1.6±0.5	2.1±0.2	2.0±0.1
Color	4.1±0.2	4.0±0.3	4.9±0.1	4.9±0.2	4.6±0.2	4.6±0.4	4.4±0.2	4.4±0.2	1.2±0.3	2.0±0.3	2.0±0.1	1.9±0.1	2.0±0.3	1.9±0.5	2.9±0.3	2.0±0.2
OA	4.4±0.1	4.3±0.2	4.9±0.2	4.8±0.1	4.7±0.1	4.7±0.5	4.9±0.1	4.9±0.3	1.6±0.2	1.8±0.5	2.6±0.3	2.2±0.2	1.8±0.2	1.8±0.6	2.8±0.2	1.8±0.2

Note: Fig in parenthesis indicate Per cent change over initial value
TBC- Total bacterial count,TMC- Total Microbial count
TD-Tray dried, TDR- Tray dried radiated, IR-Infra red dried, IRR-Infra red dried radiated.

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