



STORAGE STABILITY OF 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 (a_w) using two methods - Infrared drying (IR) and 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 (30°C and 65% RH). The physical, chemical and pathological stability were 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 color, taste, flavor, texture and overall acceptability during storage period. The growth of microbes were controlled throughout the study resulting in shelf stable IM vegetables. Among the four treatments studied, infrared dried with radiation dose of 0.75 kGy for cauliflower and 1.0 kGy for cabbage was found to be best in obtaining high quality IM products with optimum sensory, microbial, nutritional quality and storability.

Keywords: Shelf stable, Intermediate moisture, Hurdle technology, Tray drying, Infrared drying, Gamma radiation, Water activity, Polyethylene covers.

Abbreviations

HT¹ : Hurdle Technology

a_w ² : Water activity

IM³ : Intermediate Moisture

RR⁴ : Rehydration ratio,

PLW⁵ : Physiological loss of weight,

TD⁶ : Tray dried,

TDR⁷ : Tray dried radiated,

IR⁸ : Infra red dried,

IRR⁹ : Infra red dried radiated.

1. INTRODUCTION

Cauliflower (*Brassica oleracea*, var, *botrytis*) and cabbage (*Brassicaoleracea* 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 colecrop (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). 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 density. Numerous studies indicate that cauliflower contains many health beneficial phytochemicals. Brassica vegetables in general protect humans against lung, gastrointestinal tract and prostrate 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 Cruciferous vegetables 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. IM foods are easy to prepare and store without refrigeration. They require minimal energy and relatively inexpensive. They are not readily subject to spoilage, even if packages have been damaged prior to opening, as with thermo stabilized foods, because of low a_w . 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 different

preservation methods with synergistic effects. Among the newer techniques for preservation of such products, treatment with ionizing radiation is one of the most promising. The use of unhealthy and unsafe chemicals and practices can possibly be replaced by the non-residual feature of ionizing radiation 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 undertaken to study the impact of combination of infrared drying and radiation technology in processing intermediate product and increasing shelf life.

2. MATERIALS AND METHODS

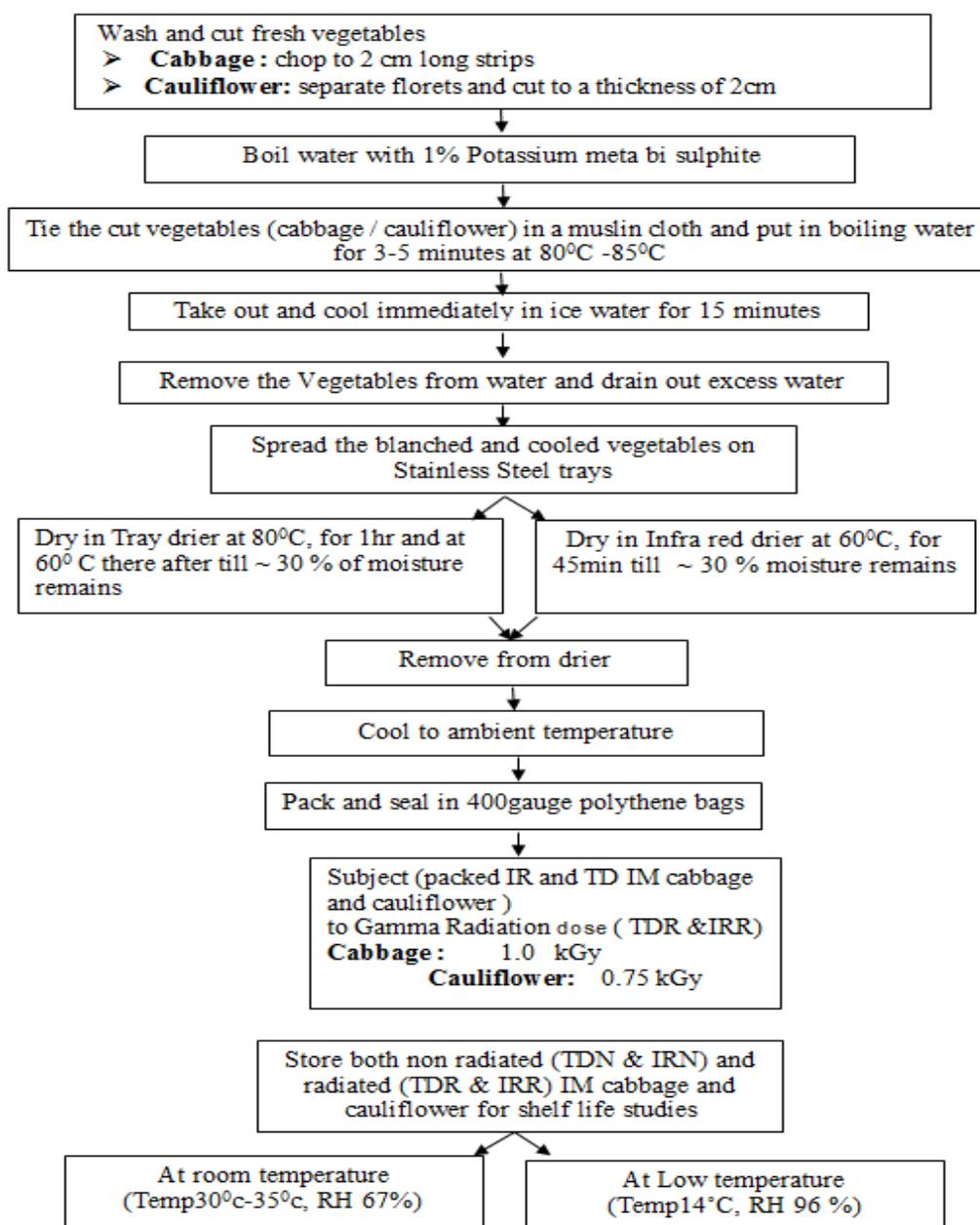
Cabbage and cauliflower were procured from local market from a single farmer (*rythu bazaar*) to maintain homogeneity in sample. After procurement vegetables were cleaned with tap water and trimmed manually.

Cabbage was chopped manually to about 2 cm long strips on a cutting board. The *Cauliflower* florets were separated and cut to a thickness of about 2 cm. To standardize the optimum pretreatment several trials like

1. *Control*: Where fresh vegetables were dried without any pretreatment.
2. *Cold water dip*: Vegetables were soaked in water containing preservative (1% of KMS) for 30 minutes at room temperature, removed, drained and dried.
3. *Blanching*: For blanching, vegetables were tied in a muslin cloth and then dipped in hot water at 85°C to which *Preservative* (1% of KMS) is added for 3-5 minutes, removed, drained and dried.
4. *Partial drying*: NaCl equivalent to 4% of partially dried product weight (dried to 50% of initial moisture content) was mixed in minimal quantity of water to dissolve the salt. The semi-dried vegetables were allowed to stand for 15 to 30 minutes in the saline solution, and subjected to drying.
5. *Combination Treatment*: A combination of several hurdles as in pre-treatments 2, 3 and 4 were applied.

Drying conditions, packaging material and radiation dose were also standardized to improve and retain the product quality. The standardized protocols were used for preparation of IM Cauliflower and cabbage is presented in Table 1. The preparation of IM Cauliflower and cabbage is presented in flow chart (Figure.1.)

Fig-1. Processing of Intermediate moisture Cauliflower and cabbage.



The following treatments were designed to ascertain the effect of radiation on shelf stability with optimal nutritional, microbial and 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 color spectrometer was used for color estimation. The most common technique to assess the color is by colorimetry. There are different color scales which measures the surface colors. 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) color (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. Per cent of loss in weight was also calculated (Ranganna, 1986).

2.1.4. Chemical Analysis

AOAC (1990) method was used for assessing moisture. Titration method was followed for estimating Vitamin C and acidity (Ranganna, 1986).

2.1.5. Microbial Analysis

For estimating viable bacterial, yeast and mold count dilution plate method was followed. For bacterial estimation, plate count agar was used and for yeast and mold potato dextrose agar was used (Krishnakumar and Devadas, 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 the results (Periaym and Pilgrim, 1957).

2.1.7. Statistical Analysis

All the experiments were repeated three times and data obtained was statistically analyzed using Analysis of Variance ANOVA (Snedcor and Cochran, 1983) two factor with replications to assess the significant difference at 0.05 % and 0.01% level using AGRES software. The impact of different treatments and interaction between storage period and treatments were compared. The product or treatment was removed from analysis of data once it got spoiled and only other three treatments were included for two factorial analysis.

3. RESULTS AND DISCUSSION

3.1. Standardization of IM Vegetables Processing

Pre-treatment is common in most processing operation to improve product quality or process efficiency (Jha and Prasad, 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 80°C and in Infra red drier (IR) at 60°C till the desired moisture level (~ 30 %) was attained Heating to appropriate temperatures for appropriate times is, essential for preserving (Azam-Ali *et al.*, 2003). The time taken for total drying 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 likereduction in drying time, providing uniform temperature in the productwhile 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), and 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 and Mattila, 1999).

A study by Sagar and Kumar (2006) reported that 200 gauge HDPE is most suitable for retention of better quality in respect to color, flavor, 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 for cauliflower and 1.0 kGy for cabbage 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-1.Standardized Protocols

vegetables	Pretreatment	Optimum dose kGy	Packing material	Mode of drying				Percent of moisture
				Infra red		Tray dried		
				Drying time (h:m)	Temp °c	Drying time (h:m)	Temp °c	
Cauliflower	Blanching 1%KMS	0.75	400 gauge poly ethylene covers	2.45	60°C	5:30	80°C	27%
				2.00	60°C	4.00	80°C	30%
Cabbage	Blanching 1%KMS	1.0	400 gauge poly ethylene covers					

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

Parameters	Before								After storage							
	Cauliflower				Cabbage				Cauliflower				Cabbage			
	TD	TDR	IR	IRR	TD	TDR	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)
Color 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

Figures in parenthesis indicate percentage

RR-Rehydration ratio, PLW –Physiological loss of weight,

TD-Tray dried, TDR- Tray dried radiated, IR-Infra red dried, IRR-Infra red dried radiated.

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 *et al.* (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, 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 (52.6%). This behavior 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 to 7 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. Vitamin C is unstable in presence of light, heat and oxygen. 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.Effect of drying and radiation on nutritional and microbial quality of IM cauliflower and cabbage stored at ambient temperature

Parameters	On Zero day								At the end of shelf life							
	Cauliflower				Cabbage				Cauli flower				Cabbage			
	TD	TDR	IR	IRR	TD	TDR	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 .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 and Motoi, 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; Yen *et al.*, 2008). Significant decrease was recorded in ascorbic acid on storage. These observations were in conformity with the findings of Harsimrat *et al.* (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 phenolic contents in the cut chinese cabbage was significantly reduced at 1 kGy or above gamma irradiation. 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. Non irradiated showed a significant increase in yeast and mold during storage when compared to radiated samples. The lower count of bacteria, yeast and mold in radiated samples may be due to DNA damage of bacteria on exposure to radiations leading to cell death (Brennan, 2006). Khattak *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 *et al.* (2000), Sawai *et al.* (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.).

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							
	Cauli flower				Cabbage				Cauli flower				Cabbage			
	TD	TDR	IR	IRR	TD	TDR	IR	IRR	TD 2m	TDR 3m	IR 4m	IRR 5m	TD 3m	TDR 5m	IR 4m	IRR 7m
Sensory score	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
Taste	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
Flavor	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
Texture	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
Color	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
OA																

Values represented are the Mean ± S.D of three independent determinations

OA- overall acceptability

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 for cauliflower and 1.0 kGy for cabbage were 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 a_w to about 0.6. Infra red drying, radiation processing and 400 gauge LDPE bags without having much effect on its physico-chemical, nutritional and organoleptic properties. Reductions in a_w , Gamma irradiation suppressed the growth of microorganisms and improved the shelf stability whereas 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.

5. ACKNOWLEDGMENT

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