ISSN NO. 2320-5407

Journal homepage: http://www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH

RESEARCH ARTICLE

Effect of different drying methods on the stability of ready-to-reconstitute idlis

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Manuscript Info

Manuscript History:

Received: 26 October 2014
Final Accepted: 22 November 2014
Published Online: December 2014

Key words:
Fermented foods, Ready-to-reconstitute idlis, Cabinet Drying, Fluidized bed drying, Microwave Drying, Shelf-life

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Abstract

Ready-to- reconstitute idlis prepared from the optimized ground batter of black gram and parboiled rice grits (1:4) were dried by cabinet drying (CD), fluidized bed drying (FBD) and microwave drying (MD) methods, packed in polypropylene (PP), metallised polyester (MP) films, stored at ambient (15-34^{0}C) and 37^0 C temperature conditions. Drying methods has significantly (p≤0.05) affected the chemical stability, texture and colour of the idlis on storage. FBD idlis showed better chemical stability followed by CD and MD idlis. MD idlis showed slightly more browning and hardness initially as well as during storage as compared to idlis dried by other methods. Idlis dried by all the three methods exhibited a shelf life of 12 months irrespective of the packaging material used and temperature of storage except MD idlis, which showed 9 months stability at 37^0 C. Microstructural studies revealed comparatively large open pores in MD idlis with better rehydration characteristics.

Introduction

Fermented foods are the important components of the diets of many parts of the world since time immemorial due to its benefits in providing high nutritive value, better organoleptic characteristics, shorter cooking time, prolonged shelf life and enhancement of flavor and aroma in foods **(Reddy and Salunkhe, 1980; Sathe et al., 1986; Das and Deka, 2012)**. Most of the fermented foods in India are region specific and carried out at the house hold scale using unique preparation methods **(Das and Deka, 2012)**. Fermented foods prepared from the combinations of cereals and legumes provide substantial amounts of vitamins and proteins in the diet of the people **(Rajalakshmi and Vanaja, 1967; Reddy et al., 1981; Sathe et al., 1986)**. Of all the fermented foods, idli, a spongy textured steam cooked product is enjoying its popularity specially in south India due to its superior digestibility, unique textural and sensory attributes **(Steinkraus et al., 1967; Kanchana et al., 2008)**. Idlis are made by the ground batters of black gram and parboiled rice taken in 1: 4 ratio **(Joseph et al., 1983)** and fermented naturally. Several research investigations have stated fermentation aspects in terms of methods of preparation of the batter, development of microbial population with time, nutritive value of the batter and its stability **(Desikachar, 1960; Steinkraus et al., 1967; Venkatasubbaiah et al., 1984; Tyagaraj et al., 1982; Agarwal et al., 2000; Rati et al., 2003, 2006; Sridevi et al., 2010; Ghosh and Chattopadhyay, 2011)**.

Fresh idlis are highly perishable and get spoiled within 24 hr of preparation. Drying is one of the most commonly used method for the preservation of foods since antiquity as it deals with the removal of moisture to resist the microbial spoilage and other deteriorative reactions **(Kroikida et al., 2003)** and extends the shelf life of stored foods. High quality dried foods with better rehydration properties are gaining worldwide demand during recent years. Different types of drying treatments have been used to obtain quality dehydrated products **(Maskan, 2001; Kotwaliwale et al., 2007; Henriques et al., 2012)**. But so far, no work was carried out on the development of dehydrated / ready-to- reconstitute idlis which gets reconstituted with the mere mixing of hot water within 4 min. However, (**Kanchana et al., 2008)** developed dehydrated idlis using various drying methods which takes 5 min soaking at 50^0 C and steaming for 15 min for rehydration.

Therefore, the present work aims at the development of dehydrated/ready-to-reconstitute idlis using cabinet drying, fluidized bed drying and microwave drying methods and their effect on the stability of idlis in different packaging materials at different temperature conditions.

MATERIALS AND METHODS

Good quality splitted dehulled black gram (Vigna mungo L) and parboiled rice was purchased from the local market of Mysore. Rice was ground coarsely and passed through the 500 mesh sieve and the material obtained through the sieve was used for making idlis. All the regents used for the study were of analytical reagent grade.

Preparation of idli batter and idlis

Splitted dehulled black gram dhal and parboiled rice grits (500µ) in a ratio of 1:4 was washed separately with distilled water and soaked for 4 hr. Soaked black gram dhal was ground to a fine paste using idli grinding machine having stone grinder, with a black gram to water ratio of 1:2. Excess of water was drained from a soaked parboiled rice grits, mixed with a fine paste of black gram dhal and 2% salt was added (calculated on the basis of the weight of unsoaked ingredients) and allowed to ferment overnight at 30^0C for 18 hr.

Fermented batter was poured in an oil smeared button idli mould which makes small idlis of approximately 3.2 -3.4 cm diameter and steam cooked for 15 min at 10 PSI pressure and divided in to 3 lots.

DRYING OF IDLIS

Cabinet drying

One lot of the steam cooked idlis were placed on drying trays and dried in a cabinet drier at 70^0C (M/s MACNEILL & MAGOR LIMITED, Mumbai, India). At every 30 min, the reduction in the mass content of idlis were recorded and the samples were dried for about 5 hr to obtain moisture content of about 7-8%.

Fluidized bed drying

The second lot of the idli samples were dried using fluidized bed drier (M/S ALLIANCE ENGINEERING, MUMBAI, INDIA) at 70^0 C where in hot air was blown through the perforated bed causing the product to flow in the shear of air and drying of idlis took sufficiently less time of around 2 hr to obtain a same moisture as above.

Microwave drying

Another lot of the idlis were dried using industrial microwave oven (ENERZI MICROWAVE SYSTEMS, Bangalore, India) which operates at a frequency of 2450 MHz containing 4 zones, each zone operating at 1.50 kw microwave power. Idlis were placed on the conveyor belt of the oven one across the other and operated at 750 W power at each zone with a conveyor speed of 20 mm/sec. The three and a half cycle was performed for drying of idlis to a desired moisture content of 7-8%. At the end of each cycle, idlis were turned to expose both the sides to heat in order to obtain an even coloured product, with 20 min for drying of one batch of idlis.

Packing and storage of dehydrated idlis

Idlis dried by all the three methods were packed in polypropylene (75 µ) as well as metallised polyester (12 µ) low density/ linear low density (150 µ) pouches, stored at ambient and 37^0C temperature conditions for shelf life evaluation.

Scanning electron microscopy

Fermented and unfermented idli batter, cut pieces of fresh and dried idlis were mounted on an aluminium stub having double stick tape on it and was coated with a gold palladium alloy by using a sputter coater (MODEL SC7620, EMITECH, UK). Coated samples were viewed in a scanning electron microscope (MODEL EVO LS 10, ZEISS TECHNOLOGY, ENGLAND) operating at an accelerated voltage of 20 kv with the desired magnification.

L* a* b* measurement

The CIE colour values (L^*, a^*, b^*) were measured using D-65 illuminant and 10^0 observer using a colour meter (MINISCAN XE PLUS, MODEL 45/0-S, HUNTER ASSOCIATES LABORATORY, INC., RESTON, VA, USA). Standard white and black tiles were used as a reference. Triplicate readings were carried out for each sample and average of the same has been reported.

Texture profile analysis (TPA)

Texture profile analysis of reconstituted idli samples dried by different methods were carried out with 50 kg load cell and P75 probe in texture analyser (MODEL TA HD^+, STABLE MICRO SYSTEMS, UK). The idlis after reconstitution were cooled to room temperature on a tissue paper to absorb excess water. The idli samples were sliced off from the top and bottom to obtain a uniform thickness on all the sides and mounted on a heavy duty platform. The test speed was set to 1 mm/sec and pre and post test speeds were maintained at 2 mm/sec respectively and the probe was allowed to compress a distance of 6 mm of idli to get TPA curve.

Sensory evaluation

Sensory evaluation of the reconstituted idlis were carried out by 20 trained panel of judges for grading the product in terms of colour, aroma, taste, texture and over all acceptability on a 9-point Hedonic scale, with 9 as excellent in all respects and 1 for unacceptable samples **(Larmond, 1977).**

Analysis

Moisture content and free fatty acid (FFA) values in ready-to-reconstitute idlis were carried out as per the method of **AOAC (1984).** Thiobarbituric acid (TBA) value was carried out as per the method described by **Tarledgis et al., (1960)**. Browning was estimated by the method of **Khan et al (2014).**Total acidity was carried out as per **AOAC 1970** methods. pH was measured using microprocessor based digital pH meter (CYBER SCAN, MODEL PH 1500, EUTECH INSTRUMENTS, India).

Raise in batter volume

The unfermented idli batter was poured in to 250 ml measuring cylinder up to 100 ml mark, covered with an aluminium foil and kept at 30^0 C and observed for the raise in batter volume after 18 hr of fermentation.

Statistical analysis

All the reported values are mean of three replicates and were subjected to three way analysis of variance (ANOVA). Significant differences ($p \leq 0.01$) between the means were tested by Duncan's multiple range test using statistical software **(Statistica, Ver. 7.1 Series 1205)** at $P \leq 0.05$ significance levels. The correlation coefficients were also calculated and tested for significance at $p<0.05$ levels.

RESULTS AND DISCUSSION

The proximate composition of idlis dried by different methods did not vary much. Protein content ranged from 13.28 -13.86% , fat 0.44-0.45%, crude fibre 0.89 - 0.91%, carbohydrate 75.15 - 75.60 % with a calorific value ranging from 358.28- 360.09 K cal/ 100g of the product. pH and total acidity of the fresh batter were 5.68 and 0.46% respectively and after 18 h fermentation pH was decreased to 4.28 with the increase in acidity to 1.02%. Also the batter volume was raised from 100 ml to 178±4 ml after 18 hr fermentation at 30^0 C.

Changes in vitamin content

The changes in vitamin B_1 and B_2 contents of idli batter (unfermented and fermented), fresh as well as dehydrated idlis dried by different methods are represented in Table-1. Vitamin B_1 and B_2 contents of unfermented batter were 0.24 and 0.26 mg/100 g respectively. After 18 h of fermentation, B_1 and B_2 contents increased to 0.44 and 0.47 mg/100g respectively. Though earlier workers have not shown the increase in B_1 content **(Desikachar et al., 1965; Sridevi et al., 2010)** during fermentation, our studies shown considerable increase in both B_1 and B_2 contents supporting well with the results obtained by **(Ghosh and Chattopadhyay, 2011)**. After steaming for 15 min, vitamin B_1 being most heat labile was lost significantly by 56.82% and B_2 by 36.17%. Also, drying of idlis by different methods has significantly ($p \leq 0.05$) reduced vitamin contents. Among the different drying methods, MD idlis reported highest reduction of B_1 (68.42%) and B_2 (46.67%) contents, while FBD idlis showed lowest reduction (B_1=42.11 % and B_2=26.67%), due to its less drying time which resulted in more retention of vitamins, while microwave heating, a high temperature short time process has attributed to the greater loss of vitamins during drying.

Changes in chemical parameters

Lipid oxidation is a major cause of the quality deterioration due to the development of rancid flavors and rejection of dehydrated foods during storage. The extent of lipid oxidation of ready-to-reconstitute idlis as measured by changes in free fatty acids (FFA), thiobarbituric acid (TBA) value and browning index (BI) dried by CD, FBD and MD methods during 12 months of storage at ambient and 37°C temperature conditions are represented in Tables 2 & 3.

Initially, the moisture content of ready-to-reconstitute idlis ranged from 7.46 to 7.99 %. During 12 months of storage moisture content in all the samples increased significantly ($p \leq 0.05$) from a minimum value of 7.46 to 8.98 and 8.85 % at ambient and 37°C temperature conditions respectively. However, the increase in moisture content was observed less in MP stored samples due to its better barrier property for moisture as compared to PP films. The rate of autoxidation as measured by changes in FFA and TBA values were not found significant ($p \geq 0.05$) initially in ready-to-reconstitute idlis dried by any of the methods. But these values increased significantly ($p \leq 0.05$) during storage of ready-to-reconstitute idlis dried by all the methods, found comparatively less in FBD idlis and more in MD idlis. During storage, FFA increased significantly ($p \leq 0.05$) from 1.19 to 5.59 & 5.84 in CD samples, 1.16 to 5.42 & 5.70 in FBD samples, from 1.22 to 5.64 & 5.97 % oleic acid in MD samples packed in PP films at ambient and 37°C temperature conditions respectively. The increase in TBA value was ranged from 0.15 to 0.52, 0.15 to 0.48 & 0.16 to 0.57 mg malonaldehyde/ kg sample in CD FBD and MD samples respectively in PP packed samples at 37^0 C (Table 3). The browning index of ready-to-reconstitute idlis also followed the same trend of increase as that of FFA and TBA values. Among the different drying methods used, MD idlis have undergone significantly ($p \leq 0.05$) more browning in comparison to FBD and CD idlis and it increased from 0.02 to 0.136 & 0.120 and 0.148 & 0.135 BI units in PP and MP films stored at ambient and 37°C temperature conditions respectively. The increased oxidation rate and browning in MD idlis may be due to the high thermal abuse of the idlis for a short period of time during microwave drying as compared to idlis dried by the other methods. Chemical changes were observed slightly more at 37°C than at ambient conditions as the storage temperature typically influences the rate of oxidation of foods. The results of the present study also depict the influence of the chemical changes on the overall acceptability of ready-to-reconstitute idlis dried by CD, FBD and MD methods. The overall acceptability (OAA) of the idlis decreased significantly ($p \leq 0.05$) during 12 months of storage. In correlation to the chemical changes observed, samples stored at 37°C scored lower acceptability scores than the samples stored at ambient temperature conditions. The initial OAA scores of CD, FBD and MD idlis were 8.21, 8.29 and 8.15 respectively on a 9 point Hedonic scale and it decreased significantly ($p \leq 0.05$) in PP films to 7.21, 7.34 & 7.02 at ambient conditions and 7.10, 7.23 & 6.76 at 37^0 C during 12 months of storage (Tables 2 & 3). It was observed that during storage, decrease in OAA score between CD and FBD idlis were not found significant but the MD idlis have shown significant decrease ($p \leq 0.05$) in overall acceptability. Since the sensory score of '7' was taken as the cut off value for accepting the product stability, the ready-to-reconstitute idlis dried by CD and FBD were found stable for the entire storage period of 12 months at both the temperature conditions where as MD idlis remained acceptable for 12 and 9 months at ambient and 37^0 C respectively.

Changes in colour value

The colour of the ready-to-reconstitute idlis has been affected by the drying temperature/time and the drying methods used (Tables 4 and 5). The idlis dried by MD has shown slightly more browning than dried by other methods. Initially, L^* value which corresponds to lightness was 62.35 for CD idlis, 63.17 for FBD idlis and 61.70 for MD idlis. There was a significant decrease ($p \leq 0.05$) in L^* and b^* values during 12 months of storage of idlis with a corresponding increase in a^* value. Initially and also during 12 months of storage, colour of the FBD idlis was appeared much brighter than idlis dried by other methods. With the increase in storage period, lightness/brightness index both in PP and MP packed samples decreased significantly ($p \leq 0.05$) from 62.35 to 56.11 & 56.42, 63.17 to 58.45 & 59.10 and 61.70 to 53.87 & 54.62 in CD, FBD and MD idlis respectively stored at 37°C temperature conditions (Table 5). The decrease in lightness was observed slightly less in samples stored at ambient conditions. The initial values for a^* were negative (-1.75 to -1.66) indicating greenness in all the dried idlis. But during storage, idlis dried by all the methods lost its greenness. The increase in a^* value was from -1.70 to 0.41 & 0.57 (CD idlis), -1.75 to 0.35 & 0.50 (FBD idlis) and -1.66 to 1.38 & 1.49 (MD idlis) in samples packed in PP films stored at ambient and 37°C temperature conditions respectively. A decrease of b^* value was observed significantly ($p \leq 0.05$) on storage of all the idlis dried by different methods. MD idlis have shown higher rate of decrease of b^* value correlating well with the slightly higher browning in them during 12 months of storage packed in PP and MP films stored at ambient and 37°C respectively (Tables 2 and 3). The decrease in L^* and b^* value and increase in a^* value of MD idlis as compared to other dried idlis may be due to the high temperature generated by microwave heater during drying in the samples that resulted in slightly more browning. **Maskan (2001)** also observed the browning of kiwi fruits during microwave drying due to the rapid browning of heat sensitive pigments at elevated temperature.

Changes in textural attributes

The textural properties which includes hardness, springiness, cohesiveness, gumminess and chewiness of rehydrated ready-to-reconstitute idlis dried by different methods packed in PP and MP films stored at ambient and 37°C are shown in Tables 6 & 7. The hardness, the force required to deform the sample increased during 12 months of storage of ready-to-reconstitute idlis dried by different methods. Significant ($p \leq 0.05$) difference between the hardness was observed among different drying methods. Initially, hardness was found slightly more in MD idlis as compared to idlis dried by any other methods. It is evident from the Tables 6 and 7 that hardness, cohesiveness and gumminess increased significantly ($p \leq 0.05$) during storage of all the idlis. Hardness increased from 7.35 to 12.18 &11.80 N in CD idlis, 7.12 to 11.60 & 11.13 N in FBD idlis and 8.12 to 13.98 & 13.45N in MD idlis during 12 months of storage at 37^0 C in PP and MP packed samples respectively. The increase in hardness in MD idlis may be due to the rapid removal of moisture during microwave drying which resulted in the collapse of capillary voids inside the product **(Kotwaliwale et al., 2007)**. Among the different drying methods, it is evident from the data that initially, cohesiveness did not change significantly ($p > 0.05$). However, during storage in PP films at ambient and 37°C temperature conditions, cohesiveness increased initially from 0.55, 0.53 & 0.62 N to 0.85 & 0.88 N, 0.80 & 0.85 N and 0.90 & 0.95 N respectively in CD , FBD and MD rehydrated idlis. However, samples stored in MP films caused lesser change in textural attributes on storage. Springiness, which indicates the elastic property decreased significantly ($p \leq 0.05$) during the storage of all the idlis dried by different methods. It is clear from the data that the difference in the springiness between PP and MP packed samples were not found significant on storage. Increase in the gumminess followed a similar trend as that of hardness and cohesiveness. Initially, gumminess was found more in MD idlis (4.80) and less in FBD idlis (3.77). Gumminess increased from 4.05 to 9.91, 9.02 & 10.71, 9.44 (CD idlis), 3.77 to 8.75, 7.57 & 9.86, 8.68 (FBD idlis) and 4.80 to 11.29, 10.29 & 13.94, 11.71 (MD idlis) packed in PP and MP films stored at ambient and 37°C respectively.

Changes in microstructure

The effect of various drying methods on the microstructural changes in fresh and ready-to-reconstitute idlis as well as fermented and unfermented batter are shown in figs 1-6. Starch granules were clearly seen in the unfermented and 18 hr fermented batter with the clear rising of the batter in 18 hr fermented one (Figs 1 & 2). Steaming of idlis for 15 min resulted in the spongy textured product with the complete disappearance of starch granules due to gelatinization (Fig 3). The porous and spongy texture in steamed idlis is attributed to the presence of foam forming protein, globulin and a polysaccharide, arabinogalactan present in black gram **(Susheelamma and Rao 1974, 1979)**. Almost similar microstructures were observed between CD and FBD idlis (Figs 4 & 5) with small pores of uniform size, may be due to the slow evaporation of moisture at low temperature used for drying, even though there was a difference in the drying time. Idlis dried by microwave has shown more porous structure as compared to CD and FBD idlis (Fig 6). Idlis when dried using microwave created big voids with large air vacuoles due to the high steam pressure formed inside the product forming the cooked starch to expand rapidly **(Chandrashekar and Chattopadhyay, 1990)**.

Rehydration characteristics.

Different drying methods used has affected the reconstitution characteristics of the idlis. Some of the idlis dried by CD and FBD methods developed crack at the centre which has affected the reconstitution. This may be due to the hardnening of the mass during drying and also due to the rapid relaxation of shrunken cells in response to the absorption of water **(Kanchana et al., 2008; Cristina et al., 2005)**. However, no crack was observed in MD idlis which took compatively less time (3 min) for reconstitution with the better structural integrity, while CD and FBD idlis took 4 min for reconstitution.

Correlation analysis

The chemical changes were found to be negatively correlated with the over all acceptability scores (OAA) of ready-to-reconstitute idlis dried by all the methods. Significant ($p<0.05$) correlation was observed between the FFA and OAA scores of idlis dried by all the methods in PP films both at ambient and 37^0 C temperature conditions, but not significant ($p>0.05$) with FFA of FBD idlis with OAA of MD idlis and FFA of CD idlis with OAA of CD, FBD and MD idlis in MP films at ambient and 37^0 C respectively. In case of TBA, correlation was found significant ($p<0.05$) between TBA of CD, FBD and MD idlis with OAA of CD and FBD idlis and TBA of CD and MD idlis with OAA of MD idlis in PP films and TBA of FBD idlis with OAA of FBD and MD idlis in MP films at ambient conditions. At 37^0 C, TBA value was found significantly ($p<0.05$) correlated with OAA scores of idlis dried by all the methods in both the packagings. Browning of CD idlis was correlated significantly ($P<0.05$) with OAA of FBD and MD idlis and browning of MD idlis with OAA of MD idlis in PP and MP films respectively at ambient conditions , while at 37^0 C, significant correlation was observed for browning of idlis with OAA scores irrespective of drying methods used in PP films. In MP films, correlation was found significant ($p<0.05$) between browning of MD idlis with OAA of CD, FBD and MD idlis and browning of CD idlis with OAA of MD idlis. For, hardness at ambient conditions, correlation was observed significant ($p<0.05$) only between CD idlis with OAA scores of CD, FBD and MD idlis and insignificant ($p>0.05$) between hardness of CD and MD samples with OAA of MD samples in MP films, while at 37^0 C, correlation was significant ($p<0.05$) between the hardness and OAA scores of idlis dried by all the methods both in PP and MP films.

Fig.1.scanning electron micrograph of unfermented idli batter at 1.0 kx showing starch granules

Fig.1.

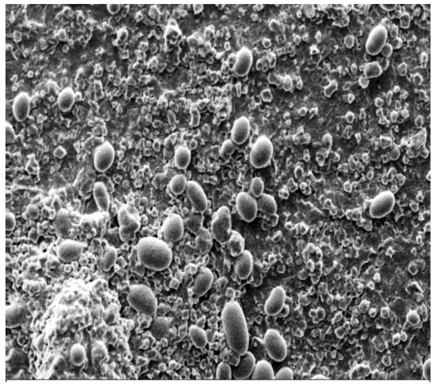

Fig.2. Scanning electron micrograph of fermented idli batter at 500 x showing starch granules as well as leavening of the batter by microbial fermentation.

Fig. 2

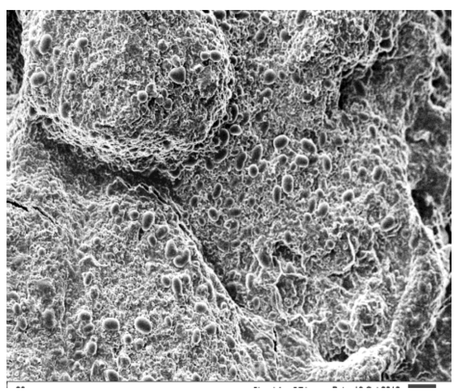

Fig.3. Scanning electron micrograph of fresh idlis at 1.0 kx showing complete deformation of starch granules with a fine network and spongy texture.

Fig. 3

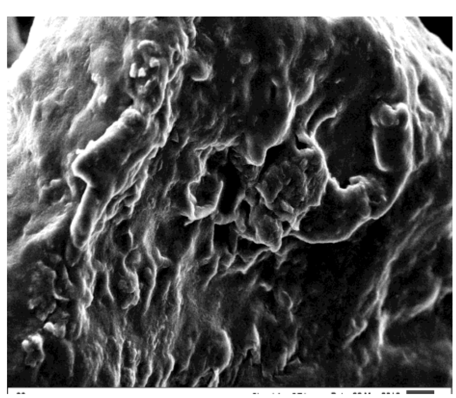

Fig.4. Scanning electron micrograph of cabinet dried (CD) idlis at 1.0 kx with a network exhibiting small pores.

Fig. 4

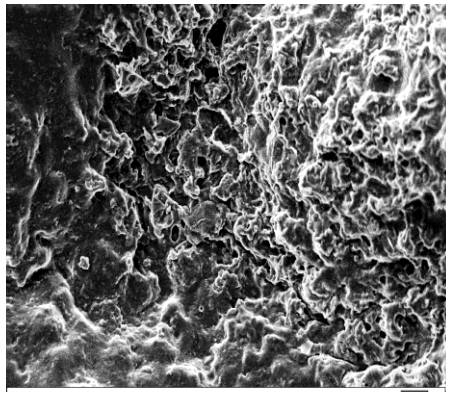

Fig.5. Scanning electron micrograph of fluidized bed dried (FBD) idlis at 1.0 kx with almost a similar structure as that of cabinet dried idlis

Fig. 5

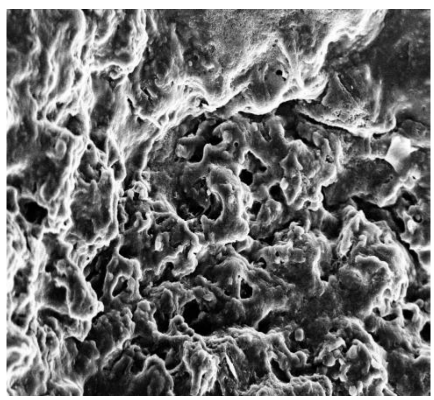

Fig.6. Scanning electron micrograph of microwave dried (MD) idlis at 1.0 kx showing large pores with void spaces.

Fig. 6

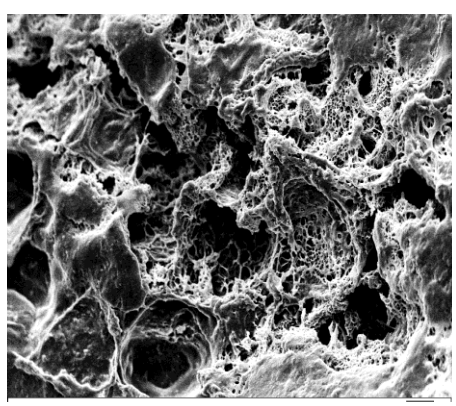

Table 1. Changes in vitamin B_1 and B_2 contents of idli batter, fresh and dehydrated idlis (mg/100g)

Drying methods	Vitamin B_1	Vitamin B_2
Unfermented batter	0.24^{a}	0.26^{a}
Fermented batter (18 h)	0.44^{b}	0.47^{b}
Frash idlis	0.19^{a}	0.30^{a}
CD idlis	0.08^{c}	0.19^{ac}
FBD idlis	0.11^{c}	0.22^{ac}
MD idlis	0.06^{c}	0.16^{c}

Values with different superscripts in columns differ significantly ($p \leq 0.05$)

Table 2. Changes in moisture, Free fatty acids (FFA, % oleic acid), Thiobarbituric acid (TBA, mg malonaldehyde/kg sample), Browning index (BI, OD) and Over All Acceptability (OAA) of ready-to- reconstitute idlis during storage at ambient conditions

Storage period (Months)										
Parameters	Pkg material	0			6			12		
		CD	FBD	MD	CD	FBD	MD	CD	FBD	MD
Moisture	PP	7.46^{a}	7.99^{b}	7.64^{c}	8.32^{d}	8.40^{e}	8.57^{f}	8.98^{g}	8.93^{g}	8.74^{h}
	MP				7.80^{i}	8.21^{j}	7.94^{b}	8.12^{k}	8.32^{d}	8.20^{k}
FFA	PP	1.19^{a}	1.16^{a}	1.22^{a}	3.42^{b}	3.38^{bg}	3.72^{c}	5.59^{de}	5.42^{d}	5.64^{e}
	MP				3.08^{f}	3.18^{fg}	3.24^{g}	4.83^{h}	4.77^{h}	5.18^{i}
TBA	PP	0.15^{a}	0.15^{a}	0.16^{a}	0.34^{b}	0.31^{bg}	0.38^{c}	0.46^{de}	0.42^{di}	0.51^{e}
	MP				0.28^{fgh}	0.26^{fg}	0.33^{bh}	0.43^{di}	0.40^{d}	0.47^{ei}
Browning	PP	0.015^{a}	0.013^{a}	0.020^{a}	0.063^{b}	0.052^{c}	0.072^{b}	0.115^{d}	0.102^{e}	0.136^{f}
	MP				0.045^{g}	0.040^{g}	0.061^{h}	0.103^{e}	0.091^{j}	0.120^{d}
OAA	PP	8.21^{a}	8.29^{a}	8.15^{a}	7.65^{b}	7.77^{b}	7.54^{bc}	7.21^{c}	7.34^{c}	7.02^{d}
	MP				7.77^{b}	7.83^{b}	7.67^{b}	7.33^{c}	7.41^{c}	7.12^{d}

Values with different superscripts differ significantly ($p \leq 0.05$)

Table 3. Changes in moisture, Free fatty acids (FFA, % oleic acid), Thiobarbituric acid (TBA, mg malonaldehyde/kg sample), Browning index (BI, OD) and Over All Acceptability (OAA) of ready-to- reconstitute idlis during storage at 37^{0} C

Storage period (Months)										
Parameters	Pkg material	0			6			12		
		CD	FBD	MD	CD	FBD	MD	CD	FBD	MD
Moisture	PP	7.46^{a}	7.99^{b}	7.64^{c}	8.20^{dh}	8.23^{dj}	8.18^{dh}	8.85^{e}	8.79^{e}	8.61^{f}
	MP				7.71^{g}	8.14^{h}	7.90^{i}	7.88^{i}	8.27^{j}	8.13^{h}
FFA	PP	1.19^{a}	1.16^{a}	1.22^{a}	3.61^{b}	3.58^{b}	3.86^{c}	5.84^{d}	5.70^{e}	5.97^{f}
	MP				3.46^{g}	3.32^{h}	3.52^{g}	5.01^{i}	5.34^{j}	5.60^{k}
TBA	PP	0.15^{a}	0.15^{a}	0.16^{a}	0.37^{b}	0.36^{b}	0.43^{cd}	0.52^{def}	0.48^{d}	0.57^{ef}
	MP				0.33^{b}	0.30^{b}	0.37^{b}	0.47^{df}	0.43^{cd}	0.51^{f}
Browning	PP	0.015^{a}	0.013^{a}	0.020^{a}	0.078^{b}	0.063^{c}	0.091^{d}	0.121^{e}	0.114^{ei}	0.148^{f}
	MP				0.064^{c}	0.051^{g}	0.082^{h}	0.110^{i}	0.101^{j}	0.135^{k}
OAA	PP	8.21^{a}	8.29^{a}	8.15^{a}	7.52^{bc}	7.65^{b}	7.35^{bc}	7.10^{cd}	7.23^{c}	6.76^{d}
	MP				7.63^{bc}	7.70^{b}	7.41^{bc}	7.22^{bc}	7.30^{bc}	6.82^{d}

Values with different superscripts differ significantly ($p \leq 0.05$)

Table 4. Changes in colour values of ready-to- reconstitute idlis during storage at ambient conditions

	Pkg material	Storage period (Months) 0			6			12		
		CD	FBD	MD	CD	FBD	MD	CD	FBD	MD
L^*	PP	62.35^{a}	63.17^{b}	61.70^{c}	59.68^{d}	61.01^{e}	57.64^{f}	56.78^{g}	59.23^{h}	54.92^{i}
	MP				59.96^{d}	61.45^{j}	58.01^{k}	57.11^{l}	59.77^{d}	55.69^{m}
a^*	PP	-1.70^{a}	-1.75^{a}	-1.66^{a}	-0.54^{b}	-0.63^{b}	0.76^{c}	0.41^{d}	0.35^{di}	1.38^{e}
	MP				-0.63^{b}	-0.78^{f}	0.50^{g}	0.33^{d}	0.26^{i}	1.20^{j}
b^*	PP	6.85^{a}	6.66^{b}	6.50^{b}	4.83^{c}	5.01^{d}	4.49^{e}	4.01^{f}	4.14^{f}	3.29^{g}
	MP				5.10^{dh}	5.22^{h}	4.72^{c}	4.44^{e}	4.28^{i}	3.44^{k}

Values with different superscripts differs significantly ($p \leq 0.05$)

Table 5**.** Changes in colour values of ready-to- reconstitute idlis during storage at 37^0 C

		Storage period (Months)								
	Pkg material	Initial			6 Months			12 Months		
		CD	FBD	MD	CD	FBD	MD	CD	FBD	MD
L^*	PP	62.35^a	63.17^b	61.70^c	58.48^d	60.83^e	56.84^f	56.11^g	58.45^d	53.87^h
	MP				59.18^i	61.20^j	57.19^k	56.42^l	59.10^i	54.62^m
a^*	PP	-1.70^a	-1.75^a	-1.66^a	-0.55^b	-0.54^b	0.99^d	0.57^e	0.50^e	1.49^f
	MP				-0.64^c	-0.67^c	0.82^g	0.49^e	0.39^g	1.34^h
b^*	PP	6.85^a	6.66^b	6.50^b	4.23^c	4.89^d	4.08^c	3.47^e	3.80^f	3.04^g
	MP				4.78^h	5.14^i	4.38^j	3.72^f	4.10^c	3.27^k

Values with different superscripts differs significantly ($p \leq 0.05$)

Table 6. Texture profile analysis of reconstituted idlis during storage at ambient conditions

Storage period (Months)										
Parameters	Pkg material	0			6			12		
		CD	FBD	MD	CD	FBD	MD	CD	FBD	MD
Hardness (N)	PP	7.35^{a}	7.12^{b}	8.12^{c}	9.89^{d}	9.66^{e}	10.94^{f}	11.66^{g}	10.94^{f}	12.54^{h}
	MP				9.70^{d}	8.78^{i}	10.46^{j}	11.42^{g}	^{j}10.23	^{h}12.38
Springiness	PP	0.80^{a}	0.76^{ab}	0.70^{b}	0.52^{c}	0.56^{cf}	0.44^{d}	0.36^{e}	0.42^{d}	0.35^{e}
	MP				0.55^{cf}	0.61^{f}	0.48^{d}	0.37^{e}	0.46^{d}	0.38^{e}
Cohesiveness	PP	0.55^{a}	0.53^{a}	0.62^{ab}	0.71^{bf}	0.67^{be}	0.76^{bcf}	0.85^{cd}	0.80^{cd}	0.90^{d}
	MP				0.65^{be}	0.62^{e}	0.70^{bcf}	0.79^{cdf}	0.74^{bf}	0.83^{d}
Gumminess	PP	4.05^{a}	3.77^{b}	4.80^{c}	7.02^{d}	6.47^{e}	8.31^{f}	9.91^{g}	8.75^{h}	11.29^{i}
	MP				6.31^{e}	5.44^{j}	7.32^{k}	9.02^{l}	7.57^{m}	10.29 ^{n}

Values with different superscripts differs significantly ($p \leq 0.05$)

Table 7. Texture profile analysis of reconstituted idlis during storage at 37^{0} C.

		Storage period (Months)								
Parameters	Pkg material	0			6			12		
		CD	FBD	MD	CD	FBD	MD	CD	FBD	MD
Hardness (N)	PP	7.35^{a}	7.12^{b}	8.12^{c}	10.23^{d}	9.89^{e}	11.66^{fk}	12.18^{g}	11.60^{f}	13.98^{h}
	MP				9.89^{e}	9.40^{i}	11.10^{j}	11.80^{k}	11.13^{j}	13.45^{l}
Springiness	PP	0.80^{a}	0.76^{ab}	0.70^{b}	0.50^{c}	0.52^{c}	0.38^{de}	0.35^{d}	0.39^{de}	0.32^{d}
	MP				0.53^{c}	0.55^{c}	0.42^{e}	0.39^{de}	0.43^{e}	0.36^{d}
Cohesiveness	PP	0.55^{a}	0.53^{a}	0.62^{ab}	0.74^{cg}	0.71^{cfh}	0.82^{dg}	0.88^{de}	0.85^{d}	0.95^{e}
	MP				0.69^{cf}	0.65^{f}	0.74^{cg}	0.80^{dg}	0.78^{gh}	0.87^{d}
Gumminess	PP	4.05^{a}	3.77^{b}	4.80^{c}	7.57^{d}	7.02^{e}	9.56^{f}	10.71^{g}	9.86^{h}	13.94^{i}
	MP				6.82^{e}	6.11^{j}	8.21^{k}	9.44^{f}	8.68^{l}	11.71^{m}

Values with different superscripts differs significantly ($p \leq 0.05$)

CONCLUSIONS

Different drying methods used for dehydration has influenced the shelf stability and acceptability of idlis. Samples dried by FBD followed by CD have shown less damage w.r.t chemical and sensory changes as compared to MD idlis. Even-though MD idlis exhibited better structural integrity with less reconstitution time and found chemically stable, the development of slightly more browning noticeable even after reconstitution has restricted the shelf life to 9 months at 37^0C. Our study concludes that microwave drying can be effectively used for the drying of idlis of superior quality, can be stored at ambient temperature to have an extended shelf life.

ACKNOWLEDGEMENTS

Authors are thankful to Director DFRL for the encouragement and also PC (FVT) in providing the facility for carrying out colour analysis.

REFERENCES

Agarwal, R., Rati, E.R., Vijayendra, S.V.N., Varadaraj, M.C., Prasad, M.S. and Nand, K. (2000): Flavour profile of idli batter prepared from defined microbial starter cultures. World. J. Microbiol. Technol. 16: 687-690.

AOAC (1970): Official Methods of Analysis. 11thedn. Association of Official Analytical Chemists. Washington, DC 20044.

AOAC (1984): Official methods of analysis, 14th edn Association of Official Analytical Chemists, Arlington, Virginia.

Chandrashekar, P.R. and Chattopadhyay, P.K. (1990): Studies on the microstructural changes of parboiled and puffed rice. 4: 27-37.

Cristina, B.S., Andres, A. and Pedro, F. (2005): Hydration kinetics of dried apple as affected by drying conditions. J. Food. Engg. 68:396-397.

Das, A.J. and Deka. S.C. (2012): Fermented foods and beverages of north India.19: 377-392.

Desikachar, H.S.R., Radhakrishnamurthy, R., Rao, G.R., Kadol, S.B., Srinivasan, M. and Subramanyam, V. (1960): Studies on the idli fermentation. 1. Some accompanying changes in the batter. J. Sci. Ind. Res. 19C: 168-172.

Ghosh, D. and Chattopadhyay, P. (2011): Preparation of idli batter, its properties and nutritional improvement during fermentation. J. Food. Sci. Technol. 48: 610-615.

Henriques, F. Guine, R.P.F. and Barroca, M.J. (2012): Influence of drying treatment on physical properties of pumpkin. Croatian. J. Food. Tech.Biotech. 7: 53-58.

Joseph, E. Crites, S.G. and Swanson, B.G. (1993): Microstructure of idli. Food structure. 12: 483-488.

Kanchana, S., Raghavan, G.S.V., Venkatesh, Sosle and Yaan, Gariepy (2008): Quality assessment of dehydrated idlis. J. Food. Sci. Technol. 45: 177-179.

Khan, M.A., Semwal, A.D., Sharma, G.K. and Bawa, A.S. (2014): Studies on the optimization and stability of instant wheat porridge (Dalia) mix. J. Food. Sci. Technol. 51: 1154-1160.

Kotwaliwale, N., Bakane, P. and Verma, A. (2007): Changes in textural and optical properties of oyster mushroom during hot air drying. J. Food. Engg. 78: 1207-1211.

Krokida, M.K., Karathanos, V.T., Maroulis, Z.B. and Marinos- Kouris, D. (2003): Drying kinetics of some vegetables. J. Food. Engg. 59: 391-403.

Larmond, E. (1977): Laboatory methods for the sensory evaluation of foods. Canada Department of Agriculture publication, pp 1637. Ottawa, Canada.

Maskan, M. (2001): Drying, shrinkage and rehydration characteristics of kiwi fruits during hot air and microwave drying. J. Food. Engg, 48: 177-182.

Rajalakshmi, R. and Vanaja, K. (1967): Chemical and biological evaluation of the effects of fermentation on the nutritive value of foods prepared from rice and grams. Bri. J. nutrn. 21: 467-473.

Rati, E.R., Vijayendra, S.V.N. and Varadaraj, M.C. (2006): Fermentation technology of some traditional foods of the Indian sub continent. In Food Biotechnol, (K. Shetty, G. Paliyath, A. Pometto, and Levin Re eds.). CRC Taylor & Francis, Boca Raton, Florida, USA, pp 1759-1794.

Rati, E.R. Vijayendra, S.V.N., Varadaraj, M.C., Nirmala Devi, S., Agarwal, R., Nana, K. and Prasad, S. (2003): Fermentation technology for smaller communities. J. Rural. Technol. 1: 28-32.

Reddy, N.R. and SalunkhE, D.K. (1980): Effects of fermentation on phytate phosphorous and mineral content in black gram, rice and black gram and rice blends. J. Food. Sci. Technol. 4: 1708-1712.

Reddy, N.R., Sathe, S.K., Pierson, M.D. and Salunkhe, D.K. (1981): Idli, an Indian fermented food: A review. J. Food.Quality. 5: 89-101.

Sathe, S.K., Reddy, N.R. and Pierson, M.D. (1986): Future of legume based fermented foods- In legume-based fermented foods. CRC press, Inc , Boea raton, FL, pp 233-235.

Sridevi, J., Halami, M.P., and Vijayendra, S.V.N. (2010): Selection of starter cultures for idli batter fermentation and their effect on the quality of idlis. J. Food. Sci. Technol. **47: 557-563.**

Steinkraus, K.H., Vanveen, A.G. and Thiebeau, D.B. (1967): Studies on idli- an Indian fermented black gram rice food. Food.Technol. 21: 110-115.

Susheelamma, N.S. and Rao, M.V.L. (1974): Surface active principle in black gram (Phaseolus mungo L) and its role in the texture of leavened food containing the legume. J. Sci. Food. Agric.25: 665-673

Susheelamma, N.S. and Rao, M.V.L. (1979): Functional role of arabinogalactan of black gram (Phaseolus mungo L) in the texture of leavened foods (Steam puddings). J. Food. Sci. 44: 1309-1313.

Tarledgis, B.G., Watts, B.M., Younathan, M.E., Dugan, L., JR. (1960): A distillation method for the qualitative determination of malonaldehyde in rancid food. J. Am. Oil. Chem. Soc. 37: 44-47.

Tyagaraja, N., Otani, H., and Hosono, A. (1992): Studies on microbiological changes during the fermentation of idli. Lebensmittel- Wissens chaft Technol, 25: 77-79.

Venkatasubbaiah, P., Dwarakanath, C.T. and Srinivasamurthy, V. (1983): Microbiological and physico-chemical changes in idli batter during fermentation. J. Food. Sci. Technol. 21: 59-62.