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Development of Induction Sealer and its Application in Food Packaging

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Abstract: Curd is a dairy product that is produced by coagulation of milk in a process known as curdling. It is one of the staples in all the pantries of our kitchen. It has the goodness of in calcium, vitamin B-2, vitamin B-12 and potassium. Recent years, sealing and packaging has become a big activity for the manufacturing sector, as proper finishing and packaging helps keep a company green as well as helps to improve a product's shelf life. Sealing is a method of sealing the product contents safely and hermetically, through cans or bottles. The dairy industry could achieve a shelf-life of 45 days by using processes of Ultra-Pasteurization (UP), while the curds/yogurt processed at Ultra-High Temperature (UHT) achieve a shelf-life of three months to one year without refrigeration. One way of improving shelf life is by sealing via the induction heating process. In this study, curd cups were sealed with specific packaging material then introduced with induction heating to increase their shelf life, considering the advantages of sealing induction and its application in food processing which is an energy efficient and renewable alternative energy source for thermal processing.

Keywords: Autoclave, heating efficiency, Incubator Shaker, Induction sealer, sealing time, sealing temperature, shelf life.

I. INTRODUCTION

The food is devoured in both its raw and cooked form. All the food items contain different amounts of water in their tissues. The water content affects different qualities and processing properties such as identification, oxidation, spoilage etc. in raw foods, also in processed products. The water content of a food or its moisture content determines its appearance, taste and texture. For biological or chemical reactions, the microbial and chemical stability of a food product is directly related to the amount of water present in a food item. The behaviour of water is a crucial factor which determines the shelf life of the food. Most bacteria do not expand at water activities less than 0.9. No mold and microbiological growth below 0.80 and 0.60 respectively are feasible. There are however a variety of food spoilage microbes that can develop within 0.8-0.6 range. It is possible to predict which microorganisms will and will not be potential causes of spoilage by evaluating the water activity.

Curd is one of the oldest produces of fermented milk. Yoghurt or curd is a strong source of B vitamins, proteins and calcium that the body can absorb much faster than fresh milk. Curd contains 85-88% water, 5-8% fat, 3.2-3.4% protein, 4.6- 5.2% lactose, 0.5-1.1% lactic acid, 0.70-0.75% ash, 0.12-0.14% calcium and 0.09-0.1% phosphorous (Laxmi Narayana et al., 1952). The dairy industry can achieve a shelf-life of 45 days by using processes of ultra-pasteurisation (UP), while the curd processed at ultra-high temperature (UHT) attain a shelf-life of three months to one year without refrigeration.

By assessing the effect of storage temperature on the microbiological stability of homogenized whole pasteurized milk wrapped in various mono-layer polyethylene (PE) products, pigmented with titanium dioxide (TiO2), the shelf life analysis evaluated. In current use for fresh yogurt, the most common material is thermoformed TiO2 pigmented high-impact polystyrene (PS-HI), with either an aluminium foil/plastic laminate or a paper/plastic laminate heat-seal coating or closure. One way of extending shelf life is by sealing via the induction heating process. Induction sealing technology consists of two main parts, the sealing head and the power supply. The head generates an electric current which is known as eddy current when energized by the power supply. The capped containers enter the electromagnetic current, and the inside seal develops electrical resistance which heats the foil. To effect, the hot foil melts the rubber coating on the inside cover. Induction machines are cheaper and do not reach the substance directly (the heat, combined with the cap pressure, causes the lip of the container to tie the inner seal to the sur-face. The effect is an airtight seal). They are less dangerous and simpler machines. Induction machines are flexible and can accommodate a range of container shapes and sizes.

II. MATERIAL AND METHODS

An induction sealer for curd packaging (which operates on the induction heating principle) was built and further research were conducted to determine the impact of Induction sealing on curd nutritional value and shelf life. Effect of storage time and temperature on parameters of quality viz. pH, total variation in colour, microbial level, taste and curd flavour were analysed.

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A. *Raw Material*

Standardized and pasteurized cow milk for curd preparation was purchased from local market. Before preparing the curd, careful care was taken to avoid cross contamination of milk. The curd was wrapped in various packing materials, viz., Aluminium foil, Wax coated aluminium foil, after curd preparation. Table 1 displays the packaging content and their purposes.

TABLE 1 DESCRIPTION OF PACKAGING MATERIAL USED FOR PACKAGING OF CURD CUPS

Packaging material	**Thickness (mm)**	**Uses**
Aluminium foil	0.800	Sealing of food item
Wax coated aluminium foil	0.024	Sealing of food item

B. *Equipment*

All the equipment used during this study were located in quality control laboratory, Department of Post-Harvest Process and Food Engineering, GBPUAT Pantnagar. The detailed equipment used along with their specification(s) and purpose are presented in Table 2.

TABLE 2 LIST OF INSTRUMENTS WITH SPECIFICATIONS

S. No.	**Name of Equipment**	**Specification(s)**	**Purpose**
1	Autoclave	Yorko make, vertical	Sterilization of medium and glass wares
2	Digital pH meter	Citizen PHS3BW microprocessor	Measuring pH of the sample
3	Heater Plate	250W	Heating the medium
4	Incubator Shaker	SANCO, plate size 420mm×420mm	To maintain the desired conditions for microbial growth
5	Vertical laminar flow	Yorko make, model VL-42 working area 4'×2×2 with profiteers	To perform the microbial analysis in sterile conditions
6	Weighing balance	AND GF-300, e = 0.01g d = 0.001g	Weighing of curd

C. *Experimental Plan*

The detailed experimental plan is presented in Fig. 1.

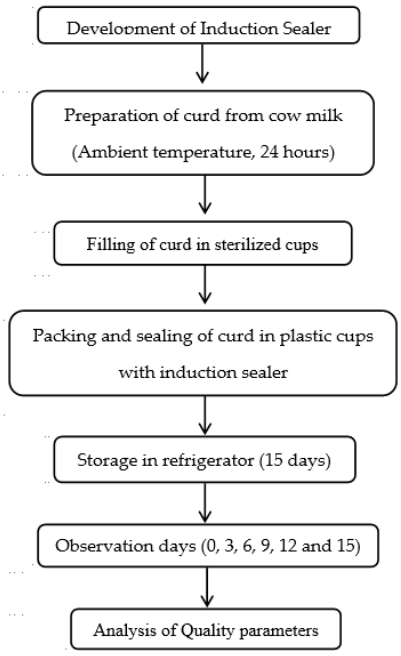

Fig.1 Detailed flow chart representing experimental plan

- Development of induction sealer

An induction sealer works based on the principle of Faraday's law of electromagnetic induction was developed in the development laboratory, Department of Electronics and Communication, GBPUAT, Pantnagar. It was developed based on amount of heat induced in different materials used for sealing viz., aluminium foil and wax coated aluminium foil. Further, the large diameter foil requires more heat as compared to small diameter foils. The developed induction heater was evaluated using curd. The physicochemical parameters of curd before and after using induction heater were recorded for further evaluation.

- Filling of sealing cups

Fresh curd (50 ml) was filled in the sterilized cups in aseptic condition. These cups were then sealed with developed induction sealer with different foil of different gauges. A set of 5-5 cups was taken. First five cups were sealed with wax coated aluminum foil (82.2 mm×0.8mm) and other five cups were sealed with aluminum foil (82.2 mm×0.024mm) and one jar was kept open.

- Storage and shelf life study

Sealed bottles were kept in refrigerator for storage and shelf life studies. Observations were recorded at an interval of 0, 3, 6, 9, 12 and 15 days to check the quality of curd (pH, total color difference, taste, flavor and overall acceptance).

III. EXPERIMENTAL DESIGN

Independent variables are selected as per the study. The levels of variables were fixed based on literature available. Various experiments were conducted for evaluating the shelf life of curd. Sensory evaluation was conducted in quality control laboratory, Department of Post-Harvest Process & Food Engineering using ten panel members (Nonsmokers and non-drinkers). The detailed independent variables along with levels and dependent variables are presented in Table 3 and Table 4 respectively.

TABLE 3 CONSTANT PARAMETERS CONSIDERED DURING EXPERIMENTATION

S. No.	Independent Variables	Average Value
1	Sealing time	30 sec
2	Sealing temperature	200°F

TABLE 4 DEPENDENT VARIABLES FOR SHELF LIFE STUDY OF CURD

Dependent variables	Method/Instrument used
pH	Digital pH meter
Microbial count	Pour plating method
Color difference	Hassani and Sharifi, 2012
Taste	Sensory test
Flavor	Sensory test
Color	Sensory test
Overall acceptance	Sensory test

A. Physicochemical Analysis of Curd

Physicochemical parameters of curd viz. pH, total colour difference was recorded on every 0, 3, 6, 9, 12, 15 days of storage. The procedure used for the analysis of each parameter are described below.

- pH

The pH of the sample was measured at ambient temperature, using a digital pH meter (Citizen PHS-3BW microprocessor) which was prior calibrated using standard buffer solution of pH 4 and pH 7.

- Total color difference

Color of the sample was determined using the combination of digital camera, computer and latest version of graphic software, Photoshop CS5. The L*, a*, b* value of curd was determined for the measurement of total color difference of

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curd. L* is the luminance of lightness component, which ranges from 0 – 100 and a (from green to red) and b (from blue to yellow) are the two chromatic compounds, which ranges from -120 to + 120.

The curd sample was poured in a petri-plate placed under light source of uniform intensity, on a light background. Digital camera was used to capture the image, the average L, a, b, value of the sample image was obtained from histogram window in Photoshop CS5. These L, a, b, values were then converted in L*, a*, b* using the following formulas.

$$L^* = \frac{Lightness}{250} \times 100$$

$$a^* = \frac{240a}{255} - 120$$

$$b^* = \frac{240b}{255} - 120$$

The total colour difference was then calculated using following formula **(Hassani and Sharifi, 2012).**

$$\Delta E = \sqrt{(\Delta L^{*2}) + (\Delta a^{*2}) + (\Delta b^{*2})}$$

Where
ΔE= total color difference
ΔL*= differential intensity of light (whiteness - blackness)
Δa* = redness/ greenness difference
Δb* = yellowness/ blueness difference

B. Microbial Analysis of Curd

The stored curd was analyzed for total viable count to evaluate the effect of pasteurization, chemical preservative and also the storage time on the microbial count. Yeats peptone dextrose (YPD) agar was used as medium growth and plating was done using pour plating method. All the instruments and materials used for microbial analysis were sterilized prior to microbial analysis to avoid the cross contamination during analysis. The procedure is described below.

- Preparation of media

YPD Agar media was prepared by adding 10 g of yeast extract, 20 g of 20 g of dextrose and 20 g of agar per liter. It was then 15 minutes autoclaved at 121 C.

- Serial dilution and plating

Sterile test tubes were filled with 9 ml of distilled water in each. 1 ml of the sample was transferred using sterile fresh 1 ml pipette to 9 ml sterile water. Again 1 ml of this suspension was transferred to the next test tube containing 9 ml of sterile water. This process was repeated 3 times to form a series of 3 dilutions.1 ml of dilution from each test tube was pipetted out into sterile plates. Then the media was poured onto it and was spreaded uniformly over the plate. The plates were then allowed to cool before closing it and were sealed by parafilm. Plates were then incubated for 24 -48 hours at 30 °C in an incubator.

- Plate counting

Plate counting was done by dividing the plate into four equal parts, the colonies in one part were counted and then multiplied by 4 to get the total number of colonies.

Colony forming unit, $CFU = \frac{No.of\ colonies \times Aliquot\ of\ sample}{Dilution\ factor}$

- Quality Assessment by Organoleptic Test (Hedonic Scale)

Hedonic scale is an organoleptic quality rating scale where the judge expresses his degree of liking is presented in Table 5 A 5 to 9-point balanced scale is used, usually a 9-point hedonic scale is preferred. This by experts and untrained consumers, but it is felt to be more applicable to the latter.

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Table 5 Nine-Point Hedonic Scale

POINT	REPRESENTATION
9	Liked extremely
8	Liked very much
7	Liked moderately
6	Liked slightly
5	Neither like nor dislike
4	Dislike slightly
3	Disliked moderately
2	Disliked very much
1	Disliked extremely

IV. RESULTS AND DISCUSSION

Prepared curd was packed in cups and sealed using an in-duction sealer then stored in a refrigerated condition. The quality parameters of curd were studied up to 15 days of storage period. The effect of induction sealing on quality parameters of curd were studied during the storage. The quality parameters studied includes physical parameters viz. pH, change in color, flavor, taste and overall acceptance. Microbial load may increase with the storage time and quality of packaging and sealing techniques. Microbial count of the samples was also determined to analyze the effect of induction sealing on the microbial load as sealing of packaging material prevent the curd from environment contamination. Induction sealing was done at 200°F for at different sealing time which was varied according to the packaging material.
Total of six samples were sealed with aluminum foil, six were sealed with wax coated aluminum foil i.e. each sample have six replication and one sample was left open as a control sample for 15 days of storage. Variation of physical parameters were obtained on three of them after 2 days interval.

A. Performance Evaluation of Induction Sealer

The performance of developed induction sealer was tested for different packaging material. It was found that the induction sealer took less time for sealing wax coated aluminum foil as compared to aluminum foil. It also preserved fresh-ness of the product. Less heat was required to make the seal, a better and a more secure seal was obtained.

B. Changes in Quality Parameters of curd during storage

After sealing the curd with induction sealer with two different materials (aluminum foil and wax coated aluminum foil) it was kept in refrigerator for determining the change in quality parameters during storage. Observations were done at an interval of 0, 3, 6, 9, 12 and 15 days for quality characteristics. The effect of induction sealing and packaging material on quality of curd were studied by taking the average values of sensory parameters which are discussed under the following headings.

- pH

pH is an important parameter which affects the sensory and nutritional quality of the product. The pH of stored curd was determined at an interval of 0, 3,6,9,12,15 days. It was found that the pH of the curd decreased with increase in storage time as depicted in Fig. 2. It was also found that the de-crease in pH was minimum in curd sealed with wax coated aluminum foil, less in case of curd sealed with aluminum foil and maximum in case of open sample. As the storage time increases, lactose present in curd is converted into lactic acid and acidity may affect pH of the sample similar finding was reported by Singh et al., (2012) for curd.

- Total color difference

For each yogurt, color stability during storage time was evaluated in terms of L*a*b* color space values. Variations of color difference (ΔE) of each yogurt between the initial time (t_0) and the expiration date (t_e) with different sealing material is shown in Fig 3. It can be seen from below graph that ΔE values were lower than 3 (not appreciated at first glance by the human eye for 3 days) but it exceeded 3 on 6th day indicating that the change of color was visible to an untrained person, whereas in case of curd sealed with aluminum foil ΔE exceeded its permissible limit on 12th day and in case of wax coated aluminum foil ΔE values were greater than 3 on 15th day.

- Microbial count

In curd samples the total bacterial populations were measured using the agar medium of the nutrient. The total number of microbial counts has been found to have increased with storage time. On the 6th day of the experiment, microbes in open curd cups reached their permissible limit. Thus, Control sample was discarded. In the case of curd, sealed with

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aluminium foil number of microbes exceeded their limit on the experiment's 12th day, whereas on the 12th day microbial growth was less in curd jars sealed with wax-coated aluminium foil. In the case of wax coated aluminium foil sealed with induction heating, the shelf life of curd rose from up to 15 days. The cause behind the raised microbes is that the dissolved oxygen increased steadily during storage in curd packed with aluminium foil, while due to its multi-layer packaging it stayed small in curd packed with wax-coated aluminium foil (Fig. 4).

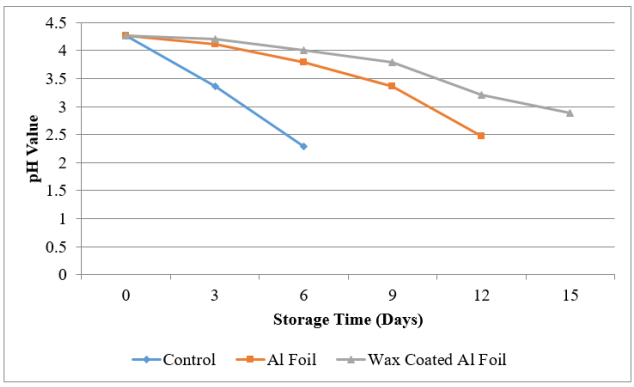

Fig. 2 Effect of storage time on pH of curd

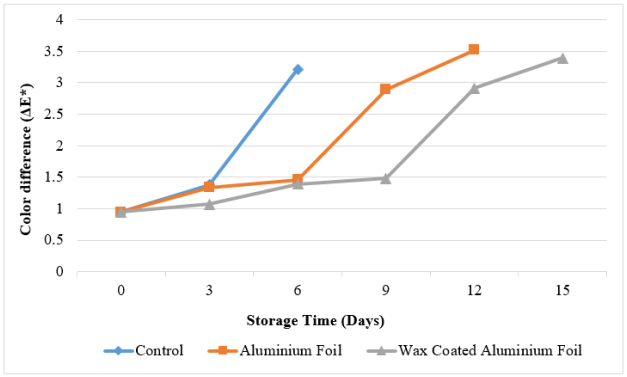

Fig. 3 Effect of storage time on color difference

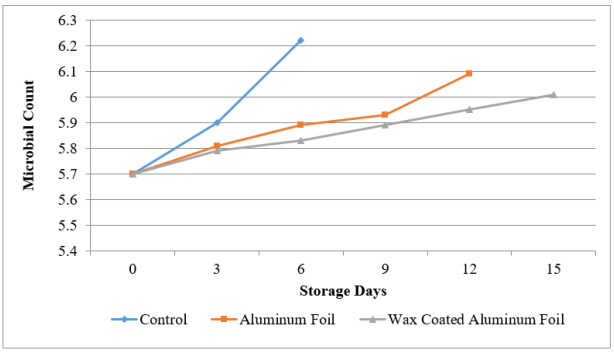

Fig. 4 Effect of storage time on microbial count of curd

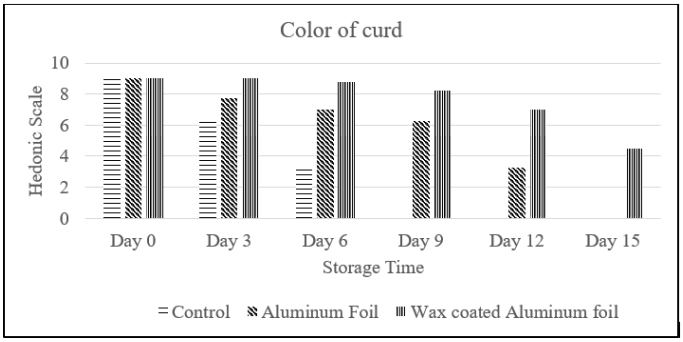

Fig 5 Effect of storage time on color of curd

C. Organoleptic Quality Assessment

Five people sampled the initial recombined samples to measure them in hedonic scale. While the quality and organoleptic level both grow from 0-9 proportionally. Every sample was graded based on texture, appearance, colour, and taste (Table 6, 7, 8 depicts the variability in curd sensory qualities with storage time and sealing material form).

TABLE 6 SENSORY ATTRIBUTES FOR CONTROL SAMPLE

Days	Color				Taste				Flavor				Overall Acceptance			
0	9	9	9	9	9	9	8	8	9	8	9	8	9	9	8	8
3	7	6	6	6	6	5	5	5	5	6	5	5	6	6	5	5
6	3	4	3	3	3	3	3	2	3	3	3	2	3	3	3	2

Table 7 Sensory attributes for aluminium foil

Days	Color				Taste				Flavor				Overall Acceptance			
0	9	9	9	9	9	9	8	8	9	8	9	8	9	9	8	8
3	7	8	8	8	8	8	7	8	8	8	7	8	7	7	8	8
6	7	7	7	7	7	7	6	7	7	6	7	6	7	7	6	6
9	7	6	6	6	6	7	6	5	6	6	6	5	6	6	6	5
12	3	4	3	3	3	3	4	3	3	3	4	3	4	3	3	3

- Colour acceptability

After (0, 3, 6, 9, 12 and 15) days of refrigeration the stored curd samples were evaluated for colour consistency. A mean colour score was taken of all the samples. It was noted that the best results were obtained from aluminium foil coated

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with wax. Due to physical, chemical and microbiological changes in curd, colour decrease with storage time acceptably (fig. 6).

TABLE 8 SENSORY ATTRIBUTES FOR WAX COATED ALUMINIUM FOIL

Days	Color				Taste				Flavor				Overall Acceptance			
0	9	9	9	9	9	9	8	8	9	8	9	8	9	9	8	8
3	9	9	9	9	9	8	8	8	9	8	8	8	8	9	8	8
6	9	8	9	9	8	8	8	8	8	8	8	8	8	8	8	8
9	9	8	8	8	8	8	8	7	8	7	7	8	8	7	8	8
12	7	7	6	8	7	8	7	6	7	7	7	7	7	7	7	7
15	5	4	4	5	5	5	4	4	4	4	4	5	5	4	4	4

- Flavour

Flavour evaluation is done by tasting and smelling the item. Similar sensory testing (as performed for colour) was conduct-ed by people of various age groups for flavour. They took the perfect score as 9. Specific deductions were made based on freshness, bitterness and rancidity. From the graph it can be seen that the curd sealed with wax-coated aluminium foil maintained its flavour for 15 days whereas it was less in aluminium foil sealed curd and less in open container (fig. 7).

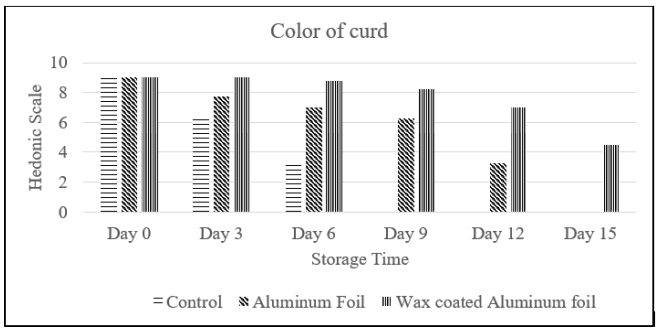

Fig 6 Effect of storage time on color of curd

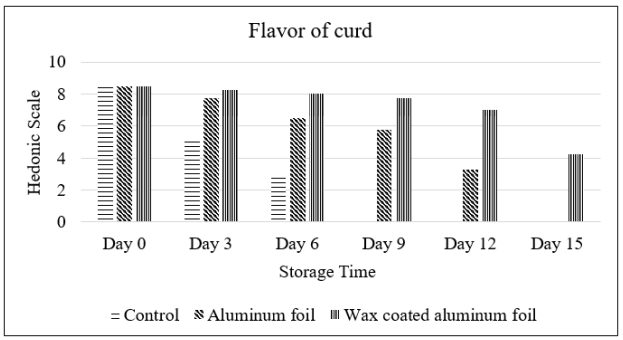

Fig 7 Effect of storage time on flavor of curd

- Taste

Sensory test for curd flavour was also carried out. 3 samples (control sample, aluminium foil sealed jars and wax coated aluminium foil sealed jars) were introduced to a 4-person jury. Each individual was asked to determine the taste. Different deductions were made due to its acidic nature, based on sourness (fig.8).

- Overall acceptance

The findings for the overall acceptance were obtained on the basis of sensory assessment. From the graph it can be seen that the overall acceptance for curd was highest for the curd sealed with wax- aluminium foil, less for aluminium foil and minimum for control sample (fig. 9).

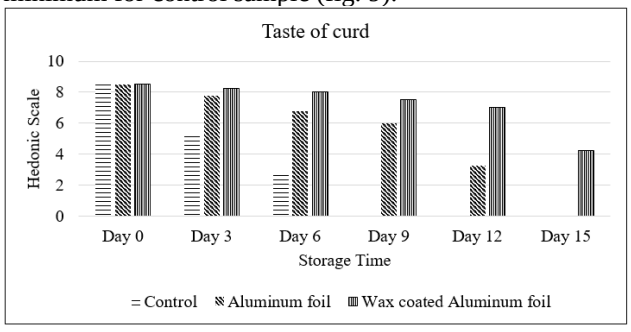

Fig. 8 Effect of storage time on taste of curd

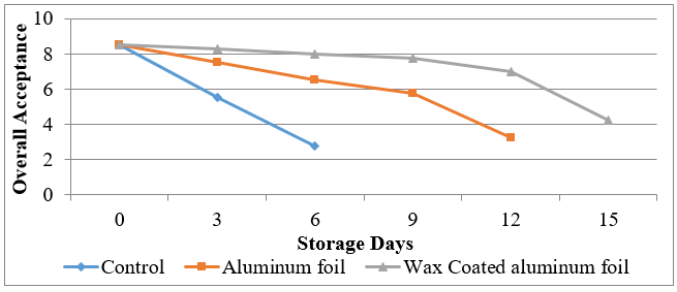

Fig. 9 Overall acceptance of curd sample

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V. CONCLUSIONS

The study result showed that the control sample pH de-creased more in the case of control sample, less in the case of aluminium foil than in the case of wax- aluminium- foil. There was also an overall increase in microbial count and colour change in the control sample, less in the case of aluminium foil and least in the case of aluminium foil coated with wax.

The following conclusions were made on the basis of experimental findings:

1. Curd sealed with wax coated aluminium foil showed lowest variation in pH and retained its permissible limit i.e. 3.01 up to 15 days whereas curd sealed with aluminium foil exceeded its permissible limit on 12th day of storage in refrigerated condition whereas control sample got spoiled on 6th day of storage. pH decreased with storage period.

2. Curd stored under refrigerated condition recorded highest number of microbial counts in control sample and it got spoiled in 6th day of storage whereas microbial count was less in case of curd sealed with aluminium foil and least in case of curd sealed with wax coated aluminium foil. Total microbial count increased with storage period.

3. It can be concluded that the shelf life of curd sealed with wax coated aluminium foil was found to be maximum and was increased from 14 to 15 days while shelf life of curd sealed with aluminium foil was found 12 days and it was 6 days in case of control sample.

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