



## Effect of incorporation of microcrystalline cellulose extracted from shallot bio-waste into low-fat stirred yogurt and its characterization

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### Abstract

Microcrystalline cellulose (MCC) extracted from shallot peel was incorporated to develop low fat stirred yogurt. MCC was added at various concentrations ranging from 0.25-1% (P<sub>1</sub>-P<sub>4</sub>) and maintained at incubation temperatures at 37(T<sub>1</sub>) and 43°C (T<sub>2</sub>). The effect of concentration of MCC and incubation temperatures on the properties of the developed yogurts were studied. The increase in incubation temperature caused an increase in fermentation rate. Hence, pH of yogurt samples was decreased from 6.66 to 4.58 in P<sub>3</sub> and P<sub>4</sub> within 5 hours at T<sub>2</sub> and 10 hours at T<sub>1</sub>. The concentration of MCC did not seem to affect the titrable acidity. At T<sub>1</sub>, a decrease of TSS in P<sub>4</sub> from 12.7 to 6.3 in the 5<sup>th</sup> hour of the fermentation was observed. As compared to T<sub>2</sub>, T<sub>1</sub> showed uniform increase of LAB count with time. Addition of MCC did not significantly affect the colour parameters, but caused an increase in moisture content upto 92.05±0.074 (P<sub>4</sub>). Total ash content increased with increase in MCC at both temperatures, while protein content reduced with increase in MCC. Syneresis was observed to be higher in samples without MCC. With an increase in temperature and concentration of MCC, a significant increase in textural characteristics was observed. The pH and TSS values of yogurt decreased over the storage period with a simultaneous increase in bacterial count, more so at T<sub>1</sub>. The sample with concentration of 1 % of MCC treated at 43 °C showed the best results compared to control samples with an acceptable microbial load.

**Keywords:** microcrystalline cellulose, low-fat, yogurt, shallot, peel, syneresis

### Introduction

Now a day, low-fat yogurt is marketed and consumed in the form of plain, set and, stirred types incorporated along with additives and processing methods. Stirred or drinkable yogurts or smoothies are more trending's with increased demand because of their convenience, nutritious and probiotic effect [1]. According to market status, the growth rate of drinkable or stirred yogurt is predicted to reach a CAGR of 18% in 2023 with the takeover of 30% of the Indian yogurt market [2, 3]. However, globally the market sales were increased to 20% with CAGR expecting to be 12.5% in 2022 [4]. The most drawback of milk is the presence of saturated fatty acid which is the leading cause for cardiovascular disorders, obesity and hypercholesterolemia condition [5]. Thus, consumer's preference for low or non-fat yogurt products has increased the awareness of milk producers to compete with innovative ideas to develop these products [6]. The most challenging part in the development and marketability of low-fat yogurts was product leads to low consumer's preference as compared to whole-fat yogurts [7].

During fermentation of milk, as it reaches the acidification stage, lactic acid bacteria converts lactose to lactic acid, calcium will expel to serum layer and fat molecules interact with casein micelles and aggregate to form three dimensional network with the help of electrostatic and hydrophobic bond formation [8]. The gel strength mainly depends on the amount of fat and protein, calcium, stirring

speed and time, temperature and pH. Fat replacers and stabilizers play an important role as hydrocolloids which improve consistency, inhibit the serum separation rate and texture and other sensory qualities. Major fat replacers are sourced from, cellulose, starch and gums from plant or animal resources [9]. This defect can be overcome by addition of good quality hydrocolloids. Commonly utilized for the commercial purpose as fat replacers and extenders are sodium caseinate, whey protein concentrate, carboxy methyl cellulose, pectin, tragacanth, almond gums and locust bean gums [10]. Especially, the modified cellulose becoming more popular in recent years due to its better air entrapment, water holding capacity, creaminess, binding capacity and stabilizer [11]. Currently, microcrystalline cellulose (MCC) is popularly gained as a versatile additive along with combined attributes such as thickener, stabilizer and fat replacer in the dairy industry. MCC is derived from purified and depolymerized cellulose with a crystalline phase [12, 13]. It shows multidimensional functionality with stable viscosity, gelling power, emulsification capacity, textural modifier, fat replacer or mimicker, heat resistance and water binder. Commercially, MCC was produced from cellulose derived from hardwood and softwood with vigorous acid hydrolysis. Recently, it also valorised from agriculture and processed biomass especially sorghum husk, cotton linters, rice husk, palm husk etc., [14] Microcrystalline cellulose has better water holding capacity among modified cellulose to form a gel-like structure that improvises the

consistency, texture and syneresis in yogurt products [11]. Stirred yogurt is commonly made by homogenising flavoured or non-flavoured yogurt to a smooth consistency and consumed as a drink. Considering the fact that stirred yogurt is usually made from whole milk in order to achieve the smoothness and consistency, the hypothesis of the current study is that incorporation of MCC can help in developing stirred yogurt from low fat milk.

Based on the aforementioned hypothesis, objective of this research mainly focused on preparation of a low-fat yogurt with addition of MCC and study the physicochemical, microbial and textural properties to varying temperature and concentration of MCC to prove as a potential stabilizer and fat replacer. Also, the storage stability was assessed for the developed yogurt under refrigerated condition.

## Material and Methods

### Material

Microcrystalline cellulose was extracted from the peel portion of shallot waste streams from Shallot processing centre at Perambalur district, Tamil Nadu, India. Selected Skim milk contains protein (3.5%), fat (0.2%), carbohydrate (5.2%) and Solid not fat (9.0%) procured from the local market, Thanjavur. Freeze-dried Starter cultures contain a combination of *Streptococcus thermophiles*, *Lactobacillus cremoris* and *Lactobacillus bulgaricus* (1:1:1) were obtained from M/s. Alla's Posh Flavours, India and stored under -12 to -18°C. All the chemicals purchased were of analytical grade from Himedia and Sigma Aldrich.

### Preparation of MCC's from shallot biowaste

Shallot peel samples were first subjected to debris segregation performed manually. This was followed by thorough washing to remove the residual soil and other foreign matters. The washed peel samples were further dried in solar drier at 50 °C to bring the moisture content to less than 5%. The dried samples were then pre-treated with autoclave along with conc. NaOH and bleaching agent. Extracted cellulose was purified excess distilled water until it attains neutral pH and oven-dried at 60°C for 24h. dried cellulose was vigorously hydrolysed with 2.5N HCl to depolymerise and form crystalline cellulose with complete removal of the amorphous region [15].

### Preparation of stirred yogurt in addition to MCC

Skim milk was pasteurized by using a water bath at 83°C for 30min and subsequently cool down to 42°C. The samples were transferred to a sterilized glass bottle and the addition of MCC at 6 treatments of 0.25% to 1.0% in each sample along with whole milk and skimmed milk at different temperatures (37°C & 45°C) and stirred well for 10min until it disperses properly. Afterwards, commercial starter culture comprising of *S. thermophiles*, *L. cremoris*, *L. bulgaricus* directly inoculated with 0.2%(w/v) as mother culture and a known quantity was transferred into samples and gently stirred for 1min [16]. The samples were prepared according to table 1 and the fermentation process was carried at T<sub>1</sub> and T<sub>2</sub> until it reaches pH 4.6. The finished products were homogenized at 9500rpm for 2min for the uniform distribution of the MCC. The yogurt samples were immediately cooled at 4°C and stored for 48h. The quality parameters were inspected throughout the processing and storage of developed stirred yogurt [17].

**Table 1:** Experimental setup for the development of MCC incorporated stirred yogurt

Extracted MCC	Treatments	Temperature (°C)	Milk (ml)	MCC (g)	Starter Culture (ml)
MCC	WMC	37(T <sub>1</sub> )	98	0	2
	SMC		98	0	2
	P <sub>1</sub>	43(T <sub>2</sub> )	97.75	0.25	2
	P <sub>2</sub>		97.5	0.5	2
	P <sub>3</sub>		97.25	0.75	2
	P <sub>4</sub>		97	1	2

Terms displayed above denotes as follows; MCC-Extraction of MCC autoclave assisted pre-treatment of shallot peel. Treatments contains in stirred yogurt preparation WMC (control-whole milk without addition), SMC (control-skim milk without addition), P<sub>1</sub> (0.25% of MCC addition), P<sub>2</sub> (0.5% of MCC addition), P<sub>3</sub> (0.75% of MCC addition) and P<sub>4</sub> (1.0% of MCC addition). T<sub>1</sub> and T<sub>2</sub> denote the two different incubation temperatures used for fermentation (37°C and 43°C).

### Physicochemical evaluation of yogurt samples.

The pH of yogurt was determined by using a digital pH meter (King's lab, Model; KLPHM-114). Titratable acidity (TA) were expressed by % of lactic acid by 0.1N NaOH by chemical titration. Total soluble solids were evaluated by using a refractometer. Turbidity is mainly expressed for microbial growth during fermentation using a microplate reader at 600nm. Similarly, the finished product was also analysed for moisture, protein, total ash colour, pH, TA, syneresis and textural characteristics [18].

### Colour parameters

Colour was measured using ColorFlex to determine the L\*, a\*, and b\* of CIE parameters. the colour intensity of each yogurt sample was determined [19].

### Serum separation rate (SSR) and syneresis

Syneresis or serum separation gives an account of whey separation from solid mass and the extent of resistance of MCC's incorporated in stirred skim milk yogurt. Ten grams of samples were taken in a centrifuge tube and were centrifuged at 4°C for 0, 3, 6, 9, 12 and 15min intervals at 1200rpm (Model-E-Spin Lark Make). The whey separated from the supernatant was quantified with a measuring cylinder [17]. The following formula was used for the determination of serum isolation rate.

$$SSR = v_2 - v_1 / v_1 \times 100$$

Where v<sub>1</sub> is the volume of the sample and v<sub>2</sub> is the volume of serum separated

### Texture evaluation

Texture attributes of stirred skim milk yogurt incorporated by MCC were evaluated by using a texture analyser, TA.XT. Plus (stable microsystem) with a 5kg load cell. The texture profile carried out by cylinder-shaped probe with 35mm diameter(A/BE-d35) with specific test speed of 1.0mm/s, penetration distance(25mm) and surface trigger at 10g by firmness, consistency, cohesiveness, work of cohesiveness and intrinsic viscosity was estimated by using test X pert software 2018 [16, 20].

**Storage studies**

The efficiency of physio-chemical and microbiological properties of MCC incorporated samples was determined through time intervals between 0, 4, 7, 14 and 28 days of storage period. In this study, pH, TSS, TA, Total plate count and syneresis rate were determined [21, 22].

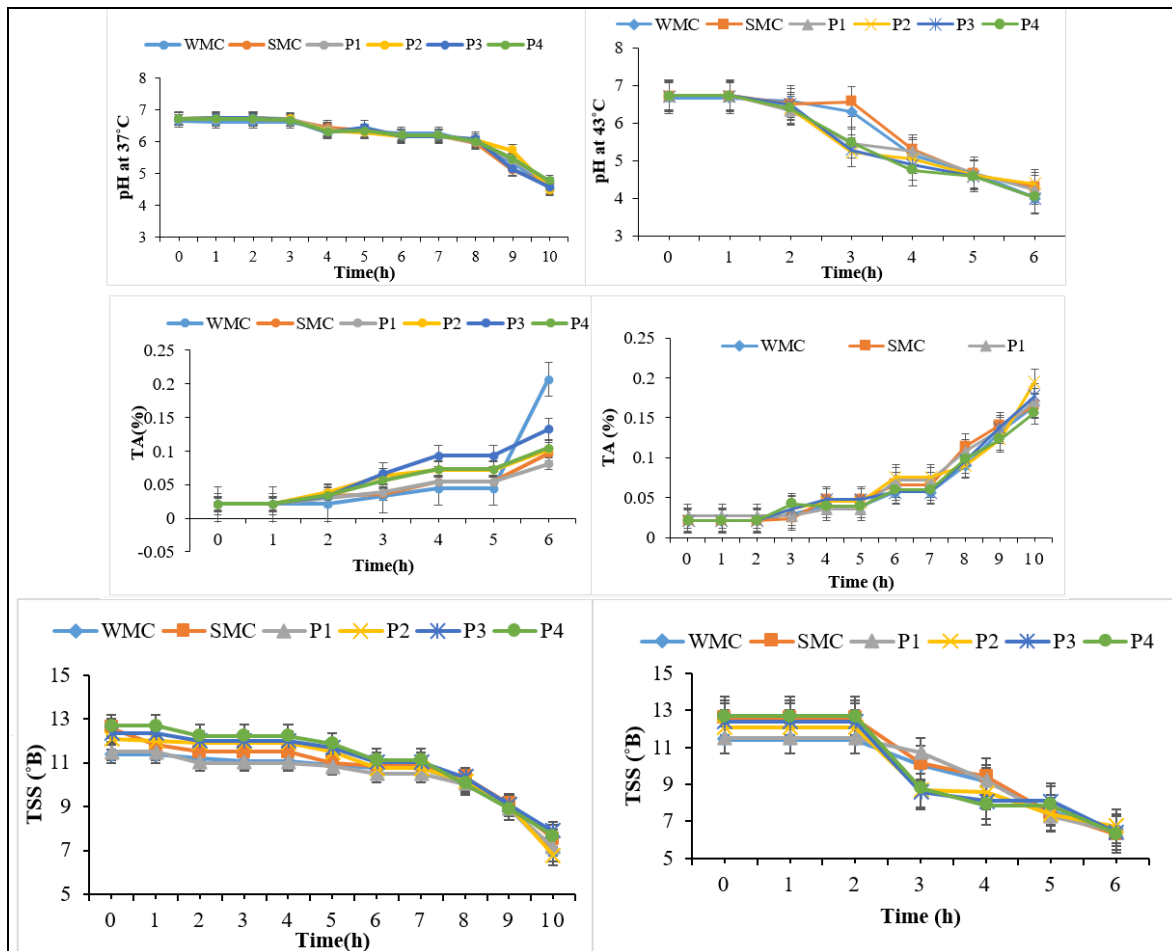
**Statistical analysis**

All the data was analysed by ANOVA according to the appropriate experimental designs and expressed as means ± standard deviation, which were then statistically compared by Tukey test at the confidence level of  $p \leq 0.05$  using Minitab 2017, version 17 (LLC, USA). All experiments were repeated in triplicates.

**Result and discussion**

**Effect of pH, titratable acidity, TSS on fermentation of MCC incorporated yogurt**

The fermentation carried out in two different temperatures at  $T_1$  (37 °C) and  $T_2$  (43 °C) in varying concentrations of MCC as illustrated in fig 1. The pH plays an important role in the development of yogurt. There were significant changes in pH at different temperatures<sup>16</sup>. As the temperature increases, the time to attain pH 4.6 was varied in samples. The pH of yogurt samples was significantly decreased from 6.66 to 4.58 in  $P_3$  and  $P_4$  within 5 hours at  $T_2$  as opposed to 10 hours at  $T_1$  in all treated samples. As the pH decreases, products are more prone to other pathogenic contamination. Hence, the fermentation process was arrested at pH 4.6 by storing at 4-5°C.



**Fig 1:** Effect of pH, TA, TSS of MCC incorporated yogurt samples during post-fermentation

TA values also showed a significant increase while fermentation in all samples treated at  $T_1$  and  $T_2$ . In WMC samples, TA values showed increase in the 5<sup>th</sup> hour and 10<sup>th</sup> hour at  $T_1$  and  $T_2$  with 0.165 and 0.207 % of lactic acid because of the increased availability of nutrients as compared to treated samples. All the treated samples also showed an increase in TA as compared to an increase in temperatures but no drastic increments with the increment of MCC. Thus the addition of MCC was not altering the fermentation with respect to TA [10].

TSS were significantly decreased during the lactic acid fermentation due to the consumption of nutrients by the rapidly growing lactic acid bacteria in the sample. In  $T_1$  and  $T_2$ , TSS drastically changed from 11.2 to 7 in WMC and SMC. At  $T_1$ , a sudden decrease of TSS in the  $P_4$  sample

from 12.7 to 6.3 in the 5<sup>th</sup> hour of the fermentation was observed. *L. bulgaricus* is known to produce proteolytic enzymes by degrading the protein to peptides and amino acids, thus stimulating the growth of *S. thermophilus* which further produces formic acid and CO<sub>2</sub> that accelerates the growth of *L. bulgaricus* and *L. cremoris*. This mixture inoculum will ferment the available lactose sugar to lactic acid [23].

**Effect of microbial growth during fermentation of yogurt in addition to MCC**

The lactic acid bacterial count is mainly dependent on the survival of bacterial culture, media and suitable temperature. While the pH reaches 4.6, the highest microbial count was showed in WMC, SMC,  $P_4$  with 5.246, 4.998 and 4.405

CFU/ml respectively. As the temperature increases, an increase in the bacterial count was showed in all samples as in fig 2. As compared to T<sub>2</sub>, T<sub>1</sub> showed uniform increase of LAB count with time. Within the short period, it attained a significant viable count as compared to T<sub>2</sub>. Within the treated sample, a significant difference was shown in the

samples treated at T<sub>1</sub>. In T<sub>1</sub>, the extent of increment of viable cell count reaches a maximum at the 10<sup>th</sup> hour due to the lag phase and an uneven growth rate was showed in each sample, the cause being the difference in incubation temperature. The addition of MCC had not significantly affected the whole fermentation process [24].

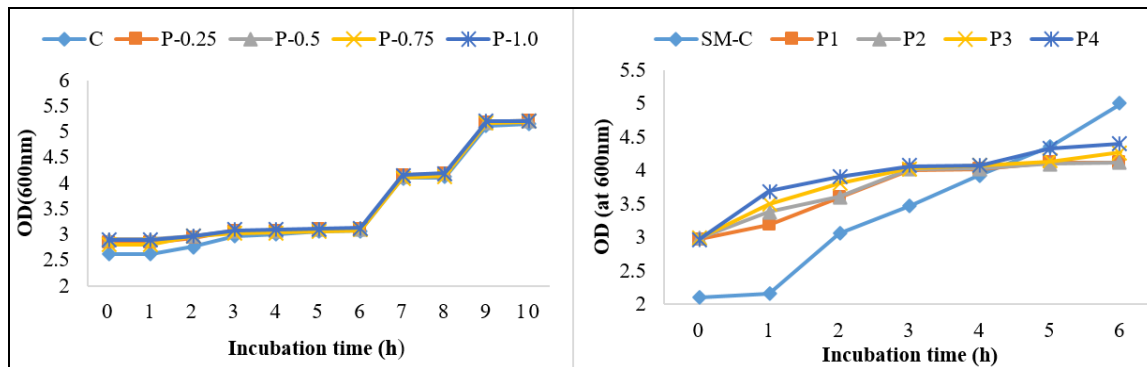


Fig 2: Changes in viable cell load through post-fermentation at T<sub>1</sub> and T<sub>2</sub> treatment

**Physicochemical properties of finished products**

The physicochemical parameters mainly observed in the finished products were colour index, moisture, total ash and protein as shown in table 2. Due to addition of MCC, there was no significant change in colour parameters as compared to control samples. Increase in the MCC concentration resulted in only a very slight decrease in the L\* a\* and b\*

values. In prior studies, some of the hydrocolloids had affected the colour attributes due to the extent of processing and storage conditions<sup>6,25</sup>. The SMC and P<sub>1</sub> showed the highest whiteness of 86.17±0.17 at T<sub>2</sub>. Moreover, fermentation temperature and time did not interfere with the quality of MCC fortified yogurt samples after 48 h refrigerated conditions.

Table 2: Physicochemical properties of MCC incorporated stirred yogurt

Samples	Moisture	Total ash	Protein	Colour index		
				L*	a*	b*
T <sub>1</sub>						
WM-C	88.83a±1.66	0.82a±0.046	4.463a±0.071	84.98±0.01	-2.06±0.03	11.07±0.02
SM-C	85.33a±3.17	0.741a±0.109	3.558b±0.041	86.41±0.03	-2.01±0.019	9.56±0.005
P <sub>1</sub>	90.67a±0.94	0.795b±0.007	4.463a±0.071	85.58±0.016	-1.51±0.04	9.65±0.016
P <sub>2</sub>	90.85a±1.85	0.941b±0.055	3.558b±0.041	84.51±0.11	-1.91±0.02	10.08±0.066
P <sub>3</sub>	91.5a±0.92	0.967b±0.579	3.471a±0.041	84.60±0.05	-1.35±0.04	9.87±0.008
P <sub>4</sub>	92.05a±0.074	1.242ab±0.092	3.238a±0.071	84.14±0.18	-1.65±0.04	10.03±0.102
T <sub>2</sub>						
WM-C	88.25±1.49	0.796a±0.014	4.463±0.071	84.98±0.01	-2.06±0.03	11.07±0.02
SM-C	86.27±0.54	0.773a±0.025	3.558±0.041	86.17±0.17	-1.64±0.01	9.57±0.01
P <sub>1</sub>	82.45±0.51	0.729c±0.05	3.471±0.041	86.17±0.04	-1.64±0.014	11.3±0.21
P <sub>2</sub>	84.5a±5.55	0.863b±0.043	3.338±0.071	84.67±0.031	-1.90±0.01	9.58±0.043
P <sub>3</sub>	87.05a±3.07	0.934ab±0.024	3.217±0.109	83.54±0.033	-1.88±0.03	8.29±0.012
P <sub>4</sub>	87.22a±1.79	1.045a±0.036	3.175±0.071	82.95±0.36	-1.55±0.025	10.36±0.029

The addition of MCC showed an influence on the moisture content in yogurt samples. The increased moisture content was showed in P<sub>4</sub> with 92.05a±0.074 owing to the porous nature of MCC that hold the water resulting in high hydrophilicity during storage. Total ash content slightly varied with increase in concentration of MCC in the yogurt samples at both fermentation temperatures. Also, highest protein content of 4.463a±0.071 at T<sub>1</sub> and 4.463±0.071 at T<sub>2</sub> was observed in WMC. The least protein content of 3.238a±0.07 at T<sub>1</sub> and 3.175±0.071 at T<sub>2</sub> was observed in P<sub>4</sub>. The slight reduction of protein can weaken the bonding between the water molecules which cause syneresis during the storage period [10, 16, 22].

**Serum separation rate and Syneresis index**

Serum separation rate predicts the initial rate of whey separation in yogurt samples during the storage period as

demonstrated in fig 3. In each interval of time, serum separation was higher in SMC with 68% at T<sub>1</sub>. While at T<sub>2</sub>, the same phenomenon was observed with 66% at 15min. During the time interval, 6minute onwards showed an increase in serum separation which give insight into the holding capacity of the hydrocolloids in yogurts samples. In addition to MCC, significant decrease in serum separation rate for a particular period as compared to control samples. The least serum separation of 42.7% was observed after 15 min at both T<sub>1</sub> and T<sub>2</sub>. Serum separation or syneresis is an important parameter in yogurt production<sup>25</sup>. The stability of samples was determined by the serum separation during 28 days. Lower the syneresis rate, the more stable will be the milk protein linkage under the acidic condition of yogurt samples<sup>23</sup>. Fig. 5 revealed that a higher rate of syneresis was found in SMC 68 % (T<sub>2</sub>). While MCC added samples, P<sub>4</sub> was more stable than other concentrations with 31.34 (T<sub>1</sub>)

and 34.67% (T<sub>2</sub>) respectively which is significantly better, SMC and WMC. Fig. 4 showed the images of serum separation that occurs in developed stirred yogurt as compared to SMC. As it can be observed, an increased level of fibres addition leads to a decrease in the syneresis values,

due to the water holding capacity of fibres that absorbed the whey released by the gel structure. The syneresis was improved compared to the control sample, since the fibres can interact through hydrogen bridges with charges moieties on the surface of the protein, thus controlling syneresis [6, 27].

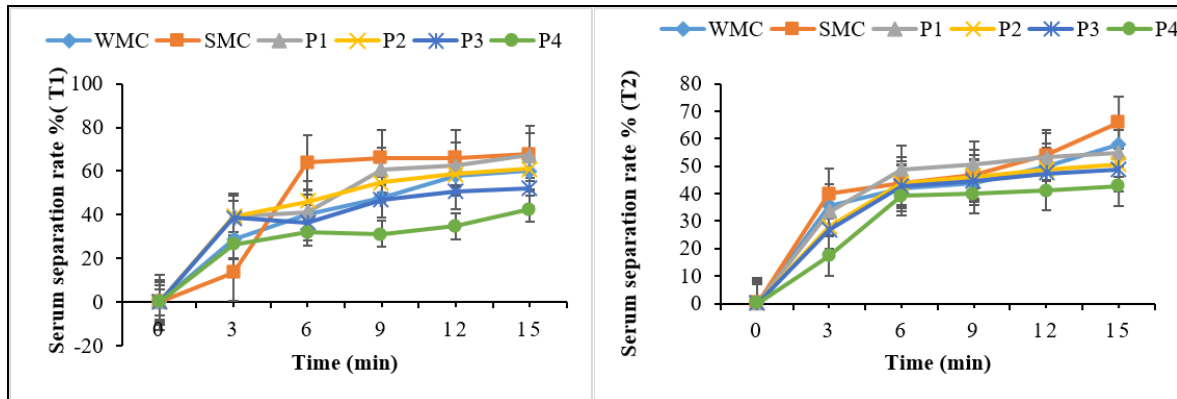


Fig 3: Changes in serum separation rate of MCC incorporated stirred yogurt at T<sub>1</sub> and T<sub>2</sub> treatments

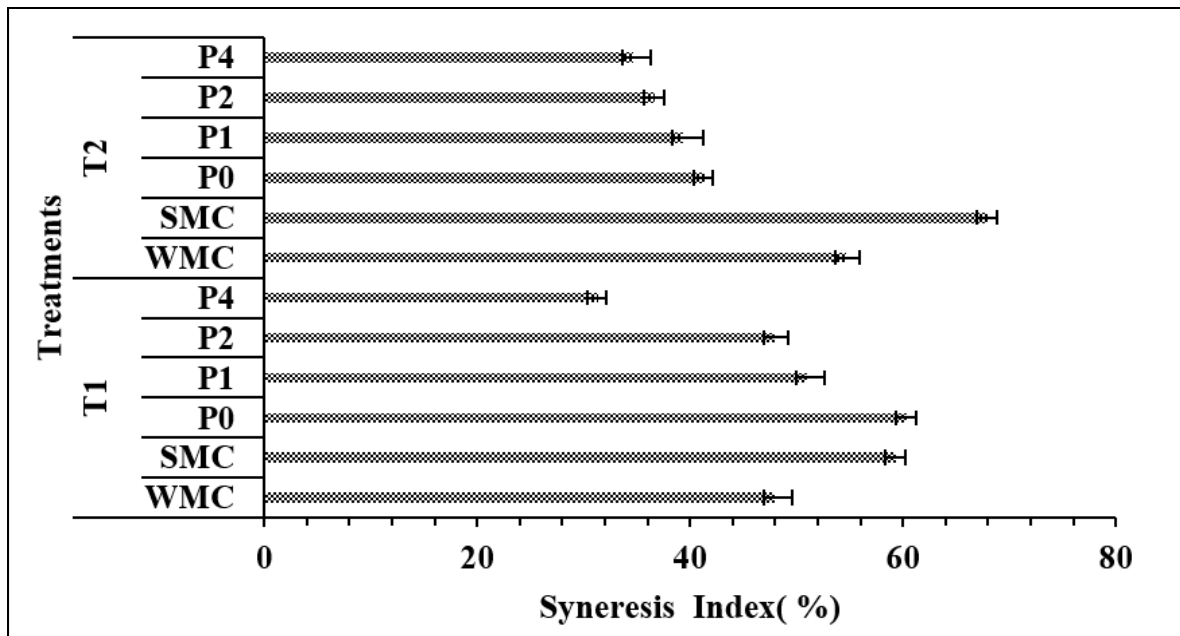


Fig 4: pattern of serum separation due to fermentation temperature and MCC concentration. (Values are presented in mean ± standard deviation.)

**Textural parameters of stirred yogurt**

**Table 3:** Textural properties of MCC incorporated stirred yogurt at T<sub>1</sub> and T<sub>2</sub>

Treatment	Firmness		Consistency		Cohesiveness		Work of Cohesion		Intrinsic viscosity	
	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2
WMC	20.12b±0.08	22.39a±1.65	418.8b±7.53	676.4a±6.54	-12.14b±0.31	-9.53a±0.925	-3.061a±1.72	-1.085a±0.34	-19.12a±7.29	-2.98a±0.74
SMC	20.47abc±0.42	19.74a±0.77	383.7a±5.88	453.4a±23.4	-11.22a±2.31	-9.18a±0.038	-3.155a±2.34	-8.897a±2.01	-2.642a±0.25	-9.178a±0.038
P1	16.86b±0.19	19.01bc±1.5	355.6e±34.0	491.45cd±8.9	-9.830a±0.92	-10.96ab±0.41	-0.82a±0	-13.7a±3.82	-3.258a±0.87	-8.948b±0.19
P2	19.74bc±0.15	20.59ab±1.08	419.5cd±23.8	614ab±23.65	-9.57a±0.35	-9.415a±0.27	-1.30a±0.23	-10.44b±0.37	-2.659a±0.33	-9.102b±0.12
P3	20.32abc±0.12	24.75ab±0.74	460.8cde±5.47	663.48a±6.41	-12.00ab±0.44	-9.105a±0.12	-1.18a±0.16	-9.98b±0.92	-4.071a±0.5	-9.764b±0.087
P4	21.66a±1.08	26.45a±2.41	547.8bc±71.5	684.51a±1.52	-14.17b±1.73	-8.95a±0.19	-1.28a±0.062	-7.00ab±0.11	-3.295a±1.28	-10.69b±0.68

\*Results are expressed as mean ± SD (n=3). Different Superscripts within the same table mean statistical difference (p < 0.05) with confidence level 95% interval.

The firmness, consistency, cohesiveness, work of cohesion and intrinsic viscosity of yogurt incorporated with MCC with varying concentration and temperature along with control samples were presented in table 3. Textural parameters are vital sensory attributes for the acceptance of consumers [27]. As the temperature and concentration of

MCC increases, a significant increase in textural characteristics observed, especially hardness [28]. This can be caused by the increased interaction between fibre and water molecules. The highest firmness was observed in the P<sub>4</sub> and P<sub>3</sub> samples with 26.45±2.41 and 24.75±0.74 at T<sub>2</sub> respectively with no significant difference (p<0.05) between

control samples. In the case of consistency, the samples treated at T<sub>2</sub> showed increased values mainly in P<sub>4</sub>, WMC and P<sub>3</sub> with values of 684.51±1.52, 676.4±6.54 and 663.48±6.41 respectively with no significant difference with other samples. Similarly, firmness, consistency and viscosity indicated a significant difference (p<0.05) in P<sub>1</sub>, P<sub>2</sub>, P<sub>3</sub> and P<sub>4</sub> treated at T<sub>1</sub> as compared to SMC. Simultaneously, hardness and cohesiveness showed a negative correlation between treated samples at T<sub>1</sub> and T<sub>2</sub> with (P<0.05). As the hardness increased, the cohesiveness of the treated sample got decreased as compared to the control samples<sup>29</sup>. A slight increase in intrinsic viscosity was observed with the increase in the addition of MCC. WMC and P<sub>4</sub> showed the highest viscosity with -19.12±7.29 and -10.69±0.68 respectively.

**Storage studies**

Table 4. Showed that the pH plays an important indicator of bacterial count in the stirred yogurt kept at 5 °C for 28 days. The pH values of stirred yogurt significantly decreased over the storage period. The initial pH of all stirred yogurt samples was about 4.65. During the period of storage, pH

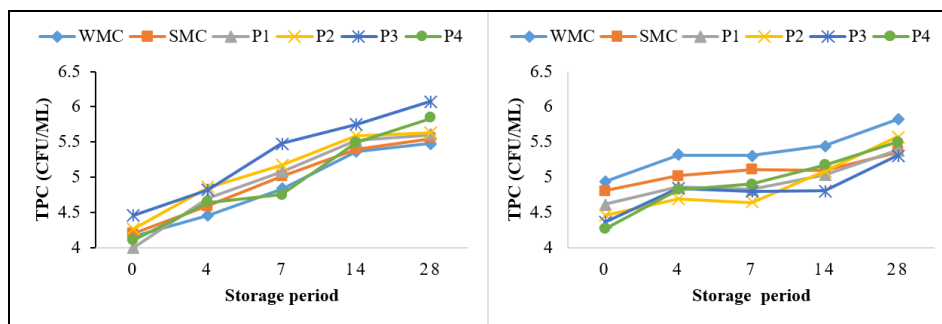
drastically decreased for samples at T<sub>1</sub> especially the WMC and SMC with 3.75±0.005 and 3.83±0.03 respectively. While in MCC added samples P<sub>4</sub> showed decreased pH at T<sub>1</sub> and T<sub>2</sub> with 3.81±0.008 and 3.69±0.012 respectively. The decrease in pH and increase in acidity of yogurt during storage is a consequence of continuing lactic acidification, which results from lactose fermentation by the associative growth of *Streptococcus thermophiles* and *Lactobacillus bulgaricus*<sup>30</sup>. This trend was remarkable as shown in prior literature<sup>31</sup>. Similarly, TSS was also reduced during the storage period due to the utilization of soluble solids for the growth of microorganisms. The maximum reduction was exhibited by WMC and P<sub>4</sub> with 5.97±0.047 at T<sub>1</sub> and 6.2±0.082 at T<sub>2</sub>. TA is inversely proportional to pH which means as pH is reduced significantly will increase the TA values of stirred yogurt samples. the TA was significantly increased in WMC than in MCC samples with 0.273±0.047 and 0.279±0.0073 respectively at T<sub>1</sub> and T<sub>2</sub>. Moreover, PMCC samples were stable up to 14 days with a limited level and then increased slightly up to 28 days within a specified level of 1.11% of lactic acid.

**Table 4:** Variation in pH, TSS and TA of yogurt samples with and without MCC

Day	0		4		7		14		28	
T	T <sub>1</sub>	T <sub>2</sub>	T <sub>1</sub>	T <sub>2</sub>	T <sub>1</sub>	T <sub>2</sub>	T <sub>1</sub>	T <sub>2</sub>	T <sub>1</sub>	T <sub>2</sub>
pH										
WMC	4.68±0.01	4.72±0.029	4.44±0.01	4.63±0.026	4.31±0.005	4.55±0.03	4.03±0.024	4.39±0.032	3.75±0.005	3.98±0.108
SMC	4.74±0.01	4.7±0.053	4.64±0.01	4.64±0.033	4.49±0.005	4.51±0.067	4.14±0.01	4.4±0.033	3.83±0.03	4.15±0.008
P <sub>0</sub>	4.65±0.04	4.65±0.028	4.56±0.009	4.61±0.023	4.2±0.0047	4.52±0.071	4.12±0.005	4.45±0.06	3.81±0.005	4.13±0.025
P <sub>1</sub>	4.62±0.02	4.66±0.037	4.5±0.01	4.63±0.032	4.29±0.061	4.56±0.043	4.14±0.005	4.43±0.045	3.84±0.02	4.1±0.015
P <sub>2</sub>	4.68±0.02	4.62±0.027	4.45±0.012	4.59±0.014	4.31±0.086	4.46±0.026	4.14±0.01	4.41±0.009	3.81±0.008	4.08±0.019
P <sub>4</sub>	4.61±0.015	4.66±0.009	4.4±0.009	4.6±0.014	4.22±0.009	4.43±0.019	4.12±0.016	4.41±0.018	3.69±0.012	4.03±0.012
TSS										
WMC	8.83±0.047	8.8±0.141	7.93±0.12	8.6±0.082	6.93±0.047	8.03±0.047	6.8±0.08	7.03±0.094	5.97±0.047	6.53±0.189
SMC	8.9±0.082	9.3±0.082	8.47±0.094	8.93±0.094	7.53±0.047	8.6±0.082	6.53±0.189	7.53±0.047	6.27±0.21	7.23±0.17
P <sub>0</sub>	8.8±0.082	9.13±0.047	8.5±0.082	8.83±0.047	7.16±0.047	8.5±0.082	6.4±0.081	8.13±0.047	6.13±0.047	7.13±0.047
P <sub>1</sub>	8.73±0.047	9±0.082	8.33±0.047	8.46±0.12	6.8±0.082	8.43±0.047	6.3±0.082	8.06±0.094	6.03±0.047	6.26±0.094
P <sub>2</sub>	8.7±0.082	8.93±0.094	8.26±0.092	8.33±0.047	7.8±0.082	8.23±0.047	6.23±0.045	7.96±0.125	6±0.082	6.3±0.141
P <sub>4</sub>	8.67±0.094	8.87±0.047	8.06±0.047	8.2±0.082	7.47±0.047	8.17±0.125	6.07±0.047	7.8±0.082	5.96±0.047	6.2±0.082
TA										
WMC	0.132±0.004	0.045±0.007	0.155±0.002	0.076±0.004	0.213±0.0042	0.129±0.004	0.234±0.007	0.216±0.0005	0.273±0.047	0.279±0.0073
SMC	0.141±0.004	0.054±0.007	0.153±0.001	0.063±0.001	0.165±0.005	0.086±0.005	0.185±0.0038	0.141±0.004	0.253±0.001	0.222±0.004
P <sub>0</sub>	0.125±0.001	0.054±0.007	0.132±0.004	0.044±0.0009	0.15±0.004	0.067±0.004	0.165±0.004	0.106±0.0031	0.19±0.0009	0.159±0.0042
P <sub>1</sub>	0.124±0.001	0.072±0.007	0.135±0.007	0.069±0.004	0.144±0.0005	0.0813±0.001	0.177±0.004	0.107±0.001	0.201±0.005	0.165±0.0045
P <sub>2</sub>	0.135±0.0005	0.093±0.004	0.141±0.004	0.105±0.004	0.145±0.004	0.111±0.004	0.189±0.0005	0.114±0.0042	0.214±0.0047	0.177±0.0045
P <sub>4</sub>	0.123±0.004	0.099±0.013	0.138±0.004	0.102±0.004	0.159±0.004	0.12±0.005	0.195±0.0037	0.129±0.0042	0.222±0.004	0.186±0.0042

In fig.5 illustrate the changes in the TPC of stirred yogurts samples. The bacterial count also started to increase during the storage period with log<sub>10</sub> CFU/ml in each sample

especially the samples treated at T<sub>1</sub> than at T<sub>2</sub>. The viable count of bacteria was too high in WMC at T<sub>2</sub>, P<sub>3</sub> and P<sub>4</sub> at T<sub>1</sub> with 5.819, 6.08 and 5.834 CFU/ml respectively.



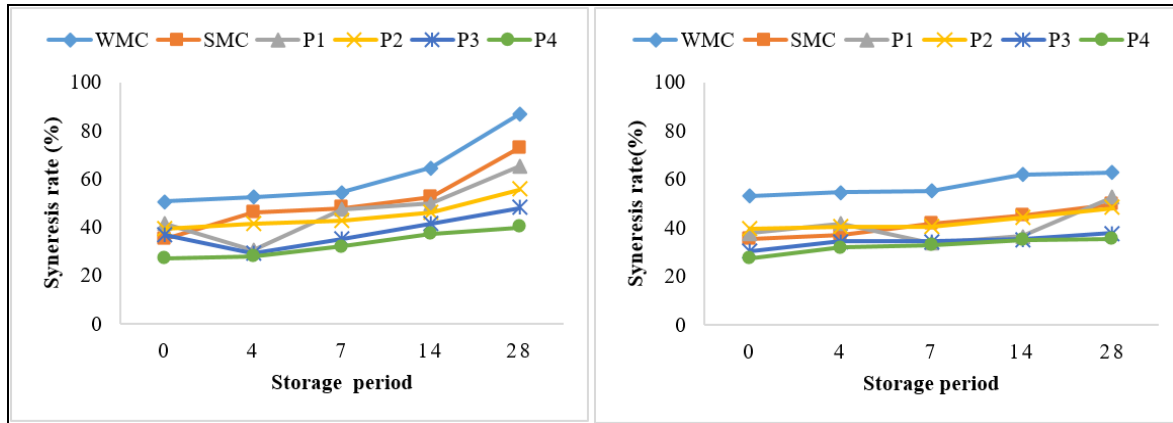
**Fig 5:** Total viable cell counts (log<sub>10</sub> CFU/ml) of probiotic yogurt drinks prepared with MCC (as a stabilizer) and control (with no additive) after 28 at 4°C.

The stability of yogurt drinks is reported in fig 6. based on the serum separation during the four weeks of storage at 5

°C. A low serum separation rate implies the stability of milk proteins in the yogurt drinks under acidic conditions. The

prepared stirred yogurt with MCC were significantly more stable than control samples ( $P < 0.05$ ). The P<sub>4</sub> at T<sub>2</sub> exhibited the lowest serum separation throughout the storage period with 35.6% as compared to control samples in refrigerated conditions. Syneresis is an undesirable phenomenon that appears as an accumulation of whey on the surface of yogurt. It is due to the rearrangements of protein aggregates leading to dense clusters that expel the serum out and can be accelerated by high incubation

temperature and external force [32]. As mentioned earlier in the effect of MCC incorporation in the moisture content, the MCC helps in holding onto water molecules owing to its high porosity. Due to this bonding of MCC to water molecules, there is a reduction in syneresis in the yogurt samples incorporated with MCC [25, 33]. However, a slight increase in syneresis could be expected in case of storage beyond 14 days, because of the saturation of MCC with water molecules [34].



**Fig 6:** Syneresis rate of stirred yogurt prepared with MCC (as a stabilizer) and controls (with no additive) after 28 days at 4°C.

## Conclusion

The microcrystalline cellulose from shallot peel has a great potential to be utilized as functional ingredients such as binder, thickener, stabilizer and fat replacer in novel product development with health functionalities. The MCC was incorporated in low fat stirred yogurt showed a positive correlation with physical, chemical, microbiological properties along with improved textural characteristics. The sample with concentration of 1 % of MCC treated at 43 °C showed the best results when in comparison to control samples with an acceptable microbial load. The MCC samples showed the excellent syneresis controller in stirred yogurt by improving the firmness and cohesiveness by desirable structural changes to the yogurt matrix during the whole process. MCC is a by-product from the processing of shallot which can also act as an effective dietary fibre, antioxidant carrier and potential texture modifier.

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