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# Enzymatic Hydrolyzed Potato Powder Stabilizes the Properties and Rheological Performance of Yogurt

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**Abstract:**

The current study emphasizes on optimizing a suitable ratio of enzymatically hydrolyzed potato powder (EHPP) and whole milk powder (WMP) to produce a quality yogurt by evaluating the physicochemical and rheological properties. The results showed that the addition of EHPP decreased the pH towards acidic conditions which resulted in the high acidity of yoghurt. The proximate composition showed that EHPP increased the ash, protein, water holding capacity (WHC) while fat, synersis, color parameters and total solid were decreased when compared to control yoghurt (CY) sample. Moreover, texture profile (TPA) analysis showed that the addition of EHPP decreased the hardness and cohesiveness while springiness did not show significant difference. Furthermore, rheological properties revealed that EHPP decreased the storage modulus (G') and loss modulus (G") when compared with control. In addition to this, sensory analysis revealed that the treatment P4M (1:3) was found as optimum ratio regarding taste, flavor, and aroma. Besides this, scanning electron microscopy (SEM) confirms that the high amount of EHPP resulted in the void holes while CY showed dense gel structure. The prepared yogurt with EHPP provides an excellent flavor, satisfying sweetness and homogeneous texture. These findings suggest the optimum formulation ratio of prepared yogurt was found to be 25% EHPP (P4M) for desirable attributes and consumer acceptance. The prepared yogurt from the EHPP presents the potential industrial applications.

**Key words:** Flavored yogurt; potato powder; physiochemical properties; microstructure; rheological properties

## 1. Introduction

Yogurt and other fermented dairy products are popular foods in the world with significant nutritional benefits. Yogurt is milk based product having high nutritional value with concentrated amount of protein, carbohydrates, fat, minerals and vitamins [1, 2]. Frozen yogurt, stirred yogurt, drinkable yogurt and firm yogurt are among the common types of yogurt, whereas, drinkable yogurt is considered as a stirred yogurt with low viscosity and its demand is increasing day by day[3]. The attractiveness of the yogurt depends upon sensory properties including flavor, aroma, texture, and appearance. These characteristics of yogurt and other fermented dairy foodstuffs depend on type of culture, milk, solid content in milk, fermentation time and temperature[3]. Moreover, textural and rheological properties play a vital role in the sensory attributes of end products. Lactic acid bacteria (LAB) have been extensively studied in the production of fermented milk. LAB occur naturally in various foods and have been utilized for centuries in the fermentation of food with multiple health benefits[4].

Recently, numerous efforts have been made to modify the quality of yogurt and to find the protected supplements from natural ingredients [3, 5]. Recent studies reported that numerous fruits and vegetables may be used in various fermented dairy products as functional ingredients and improve the sensory properties in these products[3]. Beside this, yogurt was prepared with the addition of different fruits, vegetables and fruit seed extracts to enhance the health promoting effects[6]. Thus variety of ingredients are used in yogurt formulations including dietary fiber, antioxidants, vegetable oils, fruit powders, inulin, probiotics, vitamins and minerals which have been successfully incorporated to improve the nutritional value and customer satisfaction[3, 5].

Potato (*Solunum tubersum*) is a tuber crop having starch, vitamins, carbohydrates, high value protein and low fat content, so it plays a very important role in the human health. Potato powder (a processed product of potato) has highest stability during cooling and heating process. It is used as color, thickener and flavor enhancing agent in different value added products. Some other important characteristics including gel forming properties, dough rheology, swelling ability determines the suitability of potato powder in different food formulation [7, 8]. The properties of potato powder can be modified by different enzymatic and chemical treatments. The amylases (glucoamylases β-amylases and α-amylases) are authoritative families of enzymes in the biotechnology, with α-amylases having widest range of industrial applications. A number of studies have been conducted on the kinetics of glycolysis of starch during α-amylases hydrolysis[9]. Similarly, yogurt was prepared using enzymatically hydrolyzed purple sweet potato powder by addition of α-amylase for hydrolysis [10].

Keeping in view the limited availability of studies on the effects of potato powder on physicochemical characteristics, the current study emphasizes on optimizing a suitable ratio of enzymatically hydrolyzed potato powder and whole milk powder to produce quality yogurt by evaluating the physicochemical and rheological properties. Moreover, the effects of enzymatically hydrolyzed potato powder supplementation with whole milk powder on pH, titratable acidity, and water holding capacity, syneresis, microstructure, sensory evaluation and color of the yogurt after storage at 4$^{o}$C for 24 h were carried out during this research. This study provides useful information regarding the use of potato powder in the processing and especially the optimal ratio for the development of desirable characteristics of yogurt.

## 2. Material and Methods

### 2.1. Materials

Potato powder (moisture content 7%, protein 8.6%, fat 1%, carbohydrates 81.7% and sodium 35 mg/100g) was obtained from Zhang Jiakou Yunbie Potato Development Co., Ltd., Hubei, and P.R. China. Skimmed milk powder (protein 33.4%, fat 0.8%, carbohydrates 54% and sodium 390 mg/100g), fromGMP Dairy Co., Ltd.,Beijing P.R. China. Whole milk powder (protein 23.5%, fat 26%, carbohydrates 41.5% and sodium 320 mg/100g) was obtained from Qiqihar Dairy Co., Ltd., Jingxing, Heilongjiang, P.RChina and sugar was procured from supermarket within Huazhong

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Agricultural University, Wuhan, Hubei, China. A mixed starter culture of Lactobacillus *(Lactobacillus bulgaricus*, and *lactobacillus Acidophilus)* from Beijing Chuanxiu Technology, Co., Ltd., Beijing, P.R China was used and α-amylase (4000 U/g) was purchased from Beijing Culture Media Product Field Beijing P.R China. All chemicals used in this study were of analytical grade and used without further purification.

## 2.2. Methods

### 2.2.1. Starter culture preparation

Yogurt starter culture, a combination of *Lactobacillus bulgaricus and Lactobacillus acidophilus* was obtained in freeze-dried form. The skimmed milk powder (SMP) with water (1:6) was mixed and heated at 90 ºC for 30 min using water bath. After cooling, inoculating microbial culture using percentage of 0.12% (w/v) was mixed and culture was incubated at 42 ºC for 5 to 7 h to prepare the first generation of starter with three repetitions. Continuous cultivation led to the third generation in order to obtain a fully active strain, the third starter generation was stored at 4 ºC for 24 h in a refrigerator.

### 2.2.2 Hydrolysis of potato powder

Potato powder was added in water according to (1:6) and α-amylase (0.015 g/100ml) was added and mixed at 50 °C with magnetic stirrer (DF-101S type, Wuhan Hengtaida Instrument Equipment Co., Ltd., Wuhan, P.R China). After enzymatic hydrolysis for 10 min, the mixture was placed on boiling-water bath for the inactivation of enzyme for 10 min and cooled down at room temperature for further processing.

### 2.2.3. Standardization of whole milk powder and formulations of yogurt

First of all whole milk powder (WMP) was mixed in water according to 1:6 (W/V) respectively. Subsequently subjected EHPPY formulations P1M (1:6), P2M (1:5), P3M (1:4) P4M (1:3), P5M (1:2), P6M (1: 1) (W/W) according EHPP with WMP respectively and CY (without EHPP) were prepared.

2.2.4. Preparation of EHPPY

Yogurt was prepared with WMP as previously reported methods[1, 2]. According to these procedures, the WMP and white sugar were added in EHPP and uniformly mixed, the mixture was sterilized for 15 min at 90 °C using water bath (HH-Z type, Changzhou Guohua Electric Co., Ltd., Changzhou, and P.R China). The sterilized mixture was rapidly cooled at room temperature and inoculated by 6% activated strain of yogurt culture. The inoculated mixture was fermented for 5 h at 42 °C in an incubator (model; 303A-5, Shanghai Suopu Instrument Co., Ltd., Shanghai, P.R China). After 5 h, the yogurt was placed for 24 h in a refrigerator at 4 °C for further maturation to obtain a finished product. On the second day, the obtained yogurt was mixed for 1 min by using a glass rod and was stored again at 4 ºC until further use.

2.3. Physico-chemical analysis

The physico-chemical analysis of yogurt samples was done using the following methods[12]., moisture (method No. 925-09), protein (method 920-87; N×6.38) fat (method 905.02), acidity (method 947.05), ash (method 923-03), total solids (method 990.20), pH during fermentation and after 24 h of storage at 4°C were measured using pH meter (PHS-3 pH Shanghai Electronic Co., Ltd., Shanghai, P.R China) by adopting method (No. 981.81), and acidity by method 947.05. The measurements were done in triplicates and mean values were reported.

2.3.1. Water Holding Capacity (WHC)

WHC of yogurt was measured by previously reported method[12]. For the measurement of WHC of the yogurt, 10 g sample was subjected to centrifugation at 8000 ×g at 4 ºC for 15 min. The percentage of WHC was calculated as Equation1.

$$\mathrm{WHC\%} = \mathrm{W1/W2} \times 100 \quad (1)$$

Where: W1 = Weight of drained gel, W2 = Weight of yogurt.

2.3.2. Syneresis

The centrifugation method was used to measure the physical stability of the yogurt after 24 h of storage at 4 °C by following a method reported earlier [13]. Sample (10 g) was centrifuged at 7870 × g for 10 min at 4 °C; the percentage of syneresis was calculated as Equation 2.

$$\%\ \mathrm{Syneresis} = (\mathrm{expelled\ whey(g)})/(\mathrm{Weight\ of\ yogurt(g)}) \times 100 \quad (2)$$

2.3.3. Color analysis

The color parameters of yogurt were measured as lightness ($L^*$), red/greenness ($a^*$), and yellow/blueness ($b^*$), using a CR-300 Minolta colorimeter (Osaka, Japan). Before measuring the color parameters, the colorimeter was calibrated and readings were taken in triplicate to calculate the mean value.

2.4. Texture profile analysis

Texture profile analysis (TPA) was conducted following the previously described method[15]using TA.XT2 plus Texture Analyzer (Stable Micro Systems, London, UK) equipped with a 1 kg load cell was used to determine the texture priorities of yogurt with three replications in a 100 ml beaker of 50 g yogurt that was stored for 24 h at 4 °C. The texture characteristics including hardness, adhesiveness, springiness and cohesiveness were measured by following the pre-test speed 2 mm/s, post-test speed 0.5 mm/s, measuring speed 2 mm/s, minimum triggering force 3 g, test distance 8 mm and test time 5 s with probe model P/36R. Samples were kept at 6-8 °C in ice till measurement was done at room temperature. The measurements for all samples were done in triplicates in order to calculate the mean value.

2.5. Rheology

The rheological characteristics of yogurt after 24 h storage at 4 ºC were measured by following a method described in a previous study [15]. A DHR 2 rotational rheometer (TA instruments Crawley, UK) was used for the characterization of rheological characteristics. EHPPY and CY were stored in refrigerator at 4 ºC for 24 h and before measurement of the yogurt samples were whipped 10 times clockwise and 10 times anticlockwise with a glass rod. A parallel plate geometry having 40 mm diameter stainless steel plate probe sets distance between bottom and flat 1 mm was used during analysis at 25 ºC measuring temperature. The steady shear rheological measurement was done to get with shear rate (0.1-500 $s^{-1}$) versus shear stress and viscosity curves. Fixed frequency 1Hz, strain range from 0.01-100% scan was used to determine sample constant strain 1%. Power Law Model was used to illustrate the data and demonstrate flow of yogurt samples. Shear stresses ($\tau$) were determined at the correspondent shear rates (g) obtained at 100 rpm at 25 °C. The experimental data were adapted to Power Law Model $\tau = K\gamma^n$, Where $\tau$=yield stress, $\gamma$ =shear rate K=consistency index and flow index = n of these mathematical models were applied to illustrate the flow behavior of yogurt samples[16]. Strain amplitude of 1% (within the LVR region) and 0.1-100Hz frequency ranges were used to carry out the dynamic viscoelastic measurement of the yogurt samples. G', G" and G"/G (tanδ) were obtained as function of angular frequency.

2.6. Microstructure

The morphology of yogurt samples after 24 h storage at 4 °C by following the procedure of previous study[17]. All the yogurt samples were freeze dried for 32 h under pressure 0.2 millibar fixed in liquid nitrogen using freeze dryer (Beta 2-8 LD Freeze Dryer, CHRIST Co., Ltd.,Germany). These freeze dried yogurt samples were mounted on aluminum stubs and coated by gold layer, observations were carried out through scanning electron microscope (SEM) with different magnification (Model: JSM-6390LV; NTC, Tokyo, Japan) and an accelerated voltage of 15 kV.

2.8. Sensory evaluation

The prepared yoghurt was subjected to sensory analysis in order to get the consumer's response. Hedonic scale was applied to analyze the sensory properties of yogurts. Yoghurt samples EHPPY and CY were analyzed for appearance, texture, taste, aroma, flavor and overall acceptability after 24 h storage at 4 °C. Ten panelists (5 men and 5 women) having the knowledge about quality of yogurt and food science, belong to the College of Food Science and Technology, Huazhong Agricultural University, Wuhan, Hubei, China were selected to rate the samples based on the 5 points hedonic scale [18]. Approximately 25 ml of yogurt per cup was presented to the panelists. The sensory profiles were conducted on coded in three digits random number cups containing. These sensory score included Excellent=5, Very good=4, Good=3, Average=2 and Poor=1. The panelists were also asked to make some recommendations about the sensory parameter regarding appearance, texture, taste aroma, flavor and overall acceptability of EHPPY and CY.

2.10. Statistical analysis

Software Statistix version 8.1 (stat Soft USA) was used to analyze the data by one-way analysis of variance (ANOVA). All the measurements were done in three replications and presented as a means and standard deviations. Comparisons between samples means were carried out using least significant test (LSD) test at 5% level of significant.

## 3. Results and discussion

3.1. Physico-chemical characterizes

The results of pH and acidity of yoghurt after 24 h of storage are given in Table 1. The results showed that the addition of EHPP significantly ($p < 0.05$) decreased the pH towards more acidic conditions which resulted in the increased acidity of the yoghurt compared to the control sample. Our findings regarding the changes in pH values are consistent with previous study [19], who observed lower pH values of yogurt having higher buffering capacity. The pH values may decrease from 4.68 (CY) to 3.89 (P6M) by increasing the amount of EHPP because α- amylase convert the starch into sugar and bacteria use this sugar as a food to grow more in number and convert lactose to in lactic acid, hence, cause a reduction in the pH values of yogurt. The supplementation of EHPP significantly ($p < 0.05$) affected the titratable acidity in P6M as compared to CY. After 24h of storage at 4°C, the lowest value of titratable acidity was observed in CY while the highest value was recorded for P6M (Table1). In yogurt, the titratable acidity was influenced by the different kind of proteins. It was reported that titratable acidity affect the deformation of protein and formed the original viscous [20]. The results in Table 1. revealed that the supplementation of EHPP significantly (p < 0.05) affected the moisture content of EHPPY than that of CY. The moisture content was increased from 79.67 (CY) to 83.87% (P6M) after 24 h of storage at 4 °C. The increased in moisture content might be due to the high water absorption index of potato powder compared to the milk powder. Similar findings were reported who fortified the yogurt with different minerals and their moisture contents were in the range of 80 to 85% [21].The total solids contents were decreased with the increase in EHPP due to increased water contents in yogurt (Table1). Similar findings regarding the solids were observed by the previous[21] researchers who fortified yogurt with zinc, calcium and iron. The ash content was significantly ($p < 0.05$) increased with increased supplementation of EHPP because potato powder has more minerals than milk powder and these minerals increased the ash contents in EHPPY. Similar results of ash contents were found during the preparation of organic yogurt [5]. Moreover, another study also revealed high ash contents in yoghurt with increased mineral contents[21]. The supplementation of EHPP significantly ($p < 0.05$) affected the protein content in all the treatments compared to control treatment (CY). This increase in proteins content with increase of EHPP supplementation in yogurt samples may be due to protein content found in potato powder (8.6%). Similar protein contents were found in pervious study of preparation of organic yogurt with oligofructose grape skin flour and purple grape juice [5]. The addition of EHPP significantly (p < 0.05) decreased the fat content of yoghurt compared to the control. This decrease in fat content of EHPP supplemented yogurt might be due to minute amount of fat content of potato powder. Similar fat contents were found in pervious study of preparation of yogurt with grape skin flour and purple grape juice[5].

31.1. Water holding capacity

The capability of yogurt to hold its own water is called the water holding capacity of yogurt. The results regarding the WHC of yogurt samples are displayed in the Table 1. It is apparent from the results that the WHC significantly ($p < 0.05$) increased from 40.74 to 51.07% in the CY and P6M during the storage of 24 h at 4 °C, respectively. The WHC depends on the type of protein and the amount of starch present in the formulation. The increased WHC of yoghurt with the addition of EHPP might be due to the high starch content of EHPP compared to control. Interaction between water and proteins is most significant in foodstuff systems and flavor, texture of foods affected by this interaction. The value of WHC in this study is similar with the finding of previous study [22], who observed the increased WHC with the addition of peanut (more starchy content)in milk yogurt.

**3.1.2. Syneresis**

Syneresis is an important attribute in determining the quality of yogurt. It is defined as the separation of phases in a suspension or mixture and it is natural phenomenon occurs in dairy product such as yogurt. Syneresis reflects the reduction of the gel and increase the separation of whey in yogurt which indicates the weakness of gel [23, 24]. The results showed that the addition of EHPP significantly ($p$ < 0.05) decreased the values of syneresis from 59.27 (CY) to 48.90% in P6M, respectively. This indicated that the addition of EHPP improved the gel in the yoghurt which is good attributing regarding the quality of yoghurt. This decreasing effect of EHPP supplementation on syneresis may be due to the high fat yogurt that early reported [25]. Similar results were found in yogurt with the fiber supplementation that increased the WHC of yoghurt and decreased the synersis [20]. The P4M was found to be an optimized formulation with respect to the results of synersis.

3. 1.3. Colors analysis

Color plays a significant role in determination of acceptability of numerous food products. The results regarding the effect of EHPP supplementation on the color of control and supplemented yogurt samples are displayed inTable 2. The results revealed that the addition of EHPP powder significantly ($p$< 0.05) changed the color of EHHPY samples as compared to CY. The $L*$ value decreased from initial value 98.94 in CY sample to 93.22 in P6M treatment. On the other hand, $a*$ and $b*$ values were increased in CY compared toP6M. This change in color may be attributed by potato powder andits α-amylase hydrolysis. Our findings are in line with the previously reported study of fortification of yogurt with nano and micro sized calcium, iron and zinc check the effect on the physicochemical and rheological properties[20]. On the basis of color parameters, the addition of high amount of EHPP resulted in decreased lightness while increased in redness that is not acceptable for consumer point of view. Thus, P4M was found to be in the range of color requirement for desirable yoghurt.

### 3.1.4. Texture profile analysis of yogurt

The TPA of different treatment of yogurt was evaluated after storage 24 h at 4 ºC. The texture characterizations of yogurt, including hardness, adhesiveness cohesiveness, and springiness were obviously improved by EHPP (Table 2). Hardness is an important parameter for texture of yogurt;

higher values of hardness were observed in CY, because of higher rearrangement of protein found in CY [26]. The addition of EHPP decreased the hardness significantly ($p$ < 0.05) from 92.30 in CY to 24.76 in P6M. The adhesiveness increased with increasing the EHPP, so that a tendency of high fat with EHPP becomes connected with the surface of the texture analyzer [27]. The addition of EHPP caused a remarkable reduction in fat content of yogurt, however it cannot be comparable to low fat yogurts, hence its behavior of texture properties is similar to high fat yogurt. The springiness of all the yogurt samples was increased with the increase of EHPP (Table 2).The softness of the EHPPY may be due to increase in the water due to the high absorption capacity of EHPP compared with milk powder. Moreover, the increase in springiness may attribute to higher water in gel of yogurt that means sample has ability of regain its own initial position [28]. It is apparent from the results that the addition of EHPP contributed to the significant ($p$ < 0.05) increase of cohesiveness in EHPP treated samples. However, [28] recorded higher values of cohesiveness in low fat yogurt samples. Similar results of TPA were found in optimized yogurt by micro sized calcium, iron and zinc [20]. On the basis of texture, the P4M considered as a good quality yogurt after comparison with previous published research.

## 3.2. Rheological properties of yogurt

Rheological characteristics are for huge attention, when study the properties of yogurt, because these characteristics are directly connected to use of yogurt. Fig.1 (a-e) represents the rheological properties of the yogurt with and without addition of EHPP.

### 3.2.1. Apparent Viscosity and shear stress

The results showed that the decreasing trend was found in apparent viscosity in the yogurt by increasing the addition of EHPP. The CY sample showed the high viscosity values among yogurt all samples. The results exposed that the addition of EHPP demonstrated decrease in viscosity values of stirred yogurt. This might indicate that EHPPY positively changed the texture of the yogurt. Viscosity influences the sensory characteristics and it is considered as vital quality parameter of yogurt. Rheometric viscosity has a strong positive correlation with thickness [28]. Rheological study indicates that the apparent viscosities of the entire yogurt sample decreased with increased shear rate. These phenomena reflected the shear thinning behavior of EHPPY and CY samples. The viscosities of yogurt of different EHPP are presented in all seven yogurt samples exhibits shear thinning behavior for the shear rates from 0.1 to 500 $s^{-1}$. However, the viscosity profiles for these samples were almost overlapped at most shear rates. The lower apparent viscosity of all EHPPY samples might result in high moisture contents of yogurt. However, by increasing the shear rate for both CY and EHPPY the viscosity was decreased (Fig.2a), a shear thinning behavior was found in all EHPP supplemented yogurt by following the previous study [29].Additionally, the shear stress for all the EHPPY was lower than CY at the same shear rate in (Fig.1b). This phenomenon is indicative of that there is strong interaction between molecules of starch found in potato powder and casein of milk. Shear stress change EHPPY slowly, therefore, shear stress increases in EHPPY and reaches a certain value and the curve angle first increases and then decreases, which is because of the external force of molecules would gradually be disintegrated and the stress tends to be fixed. Power law model was well fitted when the curve of shear stress with shear rate were analyzed ($R^2$>0.99) in all yogurt samples (Table 2). The flow behavior index (n) 1< as all the samples exhibited pseudoplastic behavior. Flow behavior index (n) was decreased from 0.562 in (CY) to 0.259 in (P6M) and consistency index was increased from (CY) 4.67 to (P6M) 35.47(Pa.s), with the addition of EHPP which proved that the yogurt with EHPP was more pseudo-plastic than that of CY; the entire yogurt sample exhibited the pseudo-plastic behaviors. The steady shear viscosity coefficient of CY was higher than the yogurt samples of EHPP at the relatively low shear rate. The addition of EHPP obviously affected the flow behaviors of yogurts. The model with best fit was the Power-Law model [30]. Therefore, the yogurt with EHPP exhibited improved shear thinning behavior which would compose an adequate contact between yogurt and consumers. All the yogurt samples show exhibited extremely shear thinning behavior with flow behavior index (n) as low as indicating the addition of EHPP enhanced the pseudo-plasticity of yogurt due to the reduced entanglement between starch granules [31]. The experimental yogurts were highly thixo-tropic and behaved as pseudo-plastic materials. We found significant differences ($p < 0.05$) in the rheological properties between yogurts made from milk powder and supplemented with different concentrations of EHHP. Similar results were reported by the fortification of yogurt with minerals [20]. Significantly decreased the viscosity of P4M considers as good quality yogurt as compared to the other treatments of EHPPY by following the previous above mention study.

3.2.2. Frequency sweep

All the yogurt samples showed an escalating trend in G' and G" values at lower frequencies (Fig 1c; 1d). EHPP affected the viscoelastic properties of yogurts that indicate that EHPP had no increasing effect on firmness of EHPPY (Fig 1c; 1d). The increase in G' values (Fig.1c) of CY are negligible at higher frequency, suggesting a weak gel structure for yogurt and these results are supported by initial findings of previous study[31].In contrast, more distinct increase in the G' values (Fig.1 c) was noticed for the yogurt with EHPP representing that the structure properties of yogurt have strengthened through the interaction among milk casein and molecules of starch of EHPP. The G" value (Fig.1d) for the yogurt with EHPP increased more notably with increase in angular frequency as compared with the CY. The data is reinforced by the dynamic mechanical loss tangent ($\tan \delta = G''/G$) of yogurt that displayed escalating trend as shown in the (Fig.1e). The tanδ gives the exact measure of the behavior of material as liquid like to solid like and it is dimensionless parameter. The δ value of controlled yogurt was lesser than EHPP supplemented samples. This result indicated a conversion from liquid to solid behavior and a high value of δ for yogurt with EHPP which may be resulted due to improved interaction among milk casein and starch molecules found in potato powder in the continuous phase so as to appear a strong physical system [31]. However, at the relatively elevated frequency the tan δ value for EHPPY started to decline notably which recommended that the elastic nature was succeeded above the viscous nature with EHPP addition.

### 3.3. Microstructure

Microstructure affects the texture properties, taste, flavor of food and understanding of microstructure on food quality improvement guide. Microstructures of EHPPY samples and CY are elucidated in (Fig.2).CY had dense gel structure of casein, large pore and uniform size of casein particles. The microstructure of the yogurt without addition of EHPP was much branched and displayed cross-linking in yogurt samples.SEM micrographs of the yogurts showed that the addition of EHPP led to differences in gel network. The addition of EHPP resulted in void holes and weak gel formation which resulted in low hardness of gel. With the supplementation of EHPP, the gel becomes less dense and the particle becomes more uniform and small with fluffier and coarser microstructure. Shorter fermentation time may be moderately explained as the lesser density of yogurt network. A compact and more homogenous microstructure with minor pores and particles characterized yogurt was prepared with EHPP. The same findings were found in yogurt prepared with goat milk by addition of whey protein[32]. Similarly, The consistent findings were observed in the yogurt made from modified whey protein formulations [17]. This could direct to the coarser network of the yogurts containing EHPP in the current work, because it has been confirmed that the complexes comprised by denatured whey protein and casein play a very important role in gel formation network[34]Micrograph of P4Mshowed different microstructure of yogurt as compared to the CY. This change in microstructure of P4M improved the sensory characteristic and makes it a good quality yogurt.

### 3.4. Sensory evaluation of yogurt

Sensory evaluation of control and supplemented yogurt samples was conducted using the Hedonic test (5-point scale) by 10 panelists (Fig.3). All the yogurt samples including CY and EPHH supplemented samples were evaluated for taste, appearance, texture, aroma and overall acceptability. The panelists rated higher scores to the appearance of EHPPY although there was significant ($p< 0.05$) difference in appearance existed among all yogurts. P4M were given higher scores for appearance by the panelists. The only P4M showed a significant ($p< 0.05$) difference in terms of appearance. According to sensory properties, P4M was found more acceptable by the panelists among all other treatments. For overall acceptability, appearance, taste, aroma, and texture the treatment P4M got highest scores among CY and all other EHPP supplemented yogurt samples followed by CY. The sensory scores of EHPP supplemented yogurt was related with a statistically significant($p< 0.05$) effect on sensory properties including color, flavor, and overall acceptability. The addition of EHPP to yogurt improved the flavor. Appearance score of CY and EHPPY were different significantly ($p< 0.05$). Previous study also showed the improvement in flavor and appearance of yogurt fortified with fruits and vegetables [37].

## 4. Conclusion

In the current study, EHPPY was prepared with different ratios of EHPP, where the treatment (P4M) 25% of EHPP showed improved physicochemical, texture, microstructure, rheological, color, antioxidant activity with better sensory properties of stirred yogurt. Therefore, our study supports the hypothesis that potato powder may be used as potential ingredient in yogurt due to its differential characteristics. But the high amount of EHPP can negatively affect the desirable characteristics especially WHC, texture, color and rheological properties. Thus, it is recommended that the addition of EHPP increases the yogurt acceptability which could be scaled up further, providing a basis for future studies on fermented dairy products. The storage study of newly prepared yoghurt can be a limitation of this study.

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