Development of texturized vegetable protein using indigenous sources

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Abstract
The mandate of present study was the preparation of texturized vegetable protein using indigenous sources (chick pea) as raw material and to evaluate the texturized vegetable protein based patties. As far as the effect of temperature on physical attributes is concerned it showed a linear relationship between temperature and expansion ratio with values ranging 1.85, 1.88, 1.89 and 1.92 for four treatments T1, T2, T3 and T4 respectively. T4 was most suitable value of temperature for maximum expansion. But for bulk density results were declining with increase in temperature having values ranging 0.63g/L, 0.61g/L, 0.59g/L and 0.57g/L for four treatments T1, T2, T3 and T4 respectively. The results for fat content and ash content of texturized vegetable protein were non significant. Moisture content was decreased by increasing barrel temperature of extruder. The protein of final product showed results ranging 22.39, 22.360, 22.34 and 22.33 for four treatments respectively. The color, flavor, taste, texture and overall acceptability of patties showed increasing trend with rise in temperature. Due to all attributes close to texturized vegetable protein made of soybean, the product was approved by sensory panel for use as color, texture and taste fulfilled the desired characteristics.

Keywords: Texturized vegetable protein,

Introduction
Texturized vegetable protein (TVP) has prime importance in food industry as well as from the health point of view. TVP is cholesterol free and used worldwide due to quality protein of plant source. Its utilization is also related with religious, cultural and economic issues especially it is popular in vegetarian. Also worldwide relief agencies use this product besides its utilization in child school nutrition programmes. It is easy to handle and larger shelf life than real meat and also have health benefits (Riaz, 2000).

Textured vegetable protein (TVP) are generally, those fabricated vegetable products that can be used to replace meat completely in a food serving and those textured vegetable protein entities that can be eaten in combination with meat as extenders. These textured plant protein resemble meat in chewness and flavor (Siddique, 2000). Animal protein, particularly meat is expensive and on worldwide basis in short supply (Birch et al., 1986). Hence, there is a need to make the animal protein replacer. This can be done by utilizing concentrated plant proteins and their processing. Although most vegetable proteins are of inferior quality to animal protein but legumes are good source of protein (Siddique, 2000).

Today, due to increasing consumer demand for healthy diets and concerns about rising meat prices, it is perception that plant protein based food materials will get prime importance as meat alternatives worldwide. This is the reason that various types of plant protein based meat products are now seen in the market. There are three categories of consumers. One who limits certain animal products because of religious dietary restrictions, the second group consists of those looking for a healthier alternative to meat. The third group consists of people who are looking for cheaper protein sources. Development of texturized vegetable protein is landmark of modern technology. This can help the mankind to combat with the challenges of the modern era. This is because; problems are increasing by the day. The major problems which are likely to happen include economic, cultural, religious and social problems and TVP can help in this regard (Liu, 1997).

The texturization of plant proteins has been a major development in the food industry. Processes, like extrusion, have been developed to impart a fibrous structure to amorphous plant proteins. In this production process proteins are effectively denatured during moist thermal process of extrusion. Denaturation of protein lowers solubility, renders it digestible and destroys biological activity of enzymes and toxic proteins (Smith, 1975).

Depending upon chemical composition of proteins and properties of individual constituent’s legumes especially soybean is valuable for production of texturized vegetable proteins mainly by extrusion process. Texturizing is done using high temperature, pressure and shear forces on proteineous and non-proteineous constituents, maintaining limited excess of water in extruder.(Ledward and Mitchell, 1988).

Legume grains occupy an important place in human nutrition, especially in low-income groups of people in developing countries. Legumes are prepared for consumption in many ways, such as whole legumes called grains or dehusked and split legumes, known as dhal. They are generally good sources of slow release carbohydrates and are rich in proteins (18–25%) and...
Soya bean is unique in containing about 35–43% proteins. They are also good sources of minerals and vitamins. It has been reported that germinated legumes are rich in vitamin C and in some cases there is an increase in the riboflavin as well as niacin contents upon germination. They are also the cheapest sources of supplementary proteins in vegetarians diets (Swaminathan, 1988).

Dehulled chickpea splits as chana dhal contains approximately 20.8% protein, 5.6% fat, 2.7% minerals, 1.2% fiber and 59.8% carbohydrate (Gopalan et al., 1995). The Chickpea splits are used in vast variety of forms. They may be ground to flour (besan), cooked into thick or thin gruels or combined with cereals in diverse way to make traditional foods (kitchdi, dhokla, puran poli) and used in the preparation of sweet meats (Achaya, 1984). Soybeans vary widely in nutrient content based on the specific variety and growing conditions, but typically they contain 35 to 40% protein, 15 to 20% fat, 30% carbohydrates, 10 to 13% moisture, and around 5% minerals and ash (Riaz, 2000).

Pakistan being an under developed country is facing so many problems in different fields of life and food is the major sector. Due to economic recession prevailing worldwide and affecting Pakistan as well the prices of commodities are very high, especially animal meat is not in the approach of common citizen. In this regard there is need to develop alternative ways and means of alleviating this economic decline in food sector and present study is carried out to develop an alternative of animal meat utilizing indigenous sources. As this meat alternative, so called texturized vegetable protein, is being produced in developed countries from soybean but in Pakistan due to less production of soybean, it is not economical to use soybean so chickpea is seconded due to high protein content. The mandate of present study was the preparation of texturized vegetable protein using indigenous sources as raw material and to prepare and evaluate the texturized vegetable protein based patties.

Materials and Methods

Procurement and cleaning of raw material

Raw material (chickpea) was purchased from Ayub Agriculture Research Centre Faisalabad and cleaned manually in order to remove dust particles and stones, damaged seeds, seeds of other crops and other impurities such as weeds and metals. After cleaning, grains were dehulled and again cleaned manually. Dehulled and cleaned grains of chickpea were milled to get flour of size 15-20 mesh size for further process of extrusion (Riaz, 2000).

Extrusion Process

The texturized vegetable protein prepared from chickpea source used in this study was made on a single screw extruder (Extru-Tech, Inc. Model # KN, Sabetha, Ks 66534). The extrusion process was carried out as directed by Sakatal et al., (1999). The extruder was fitted with a 2 start screw and a 2-hole die with 4 mm apertures. The ingredients were fed in the form of chickpea flour of 15 to 20 mesh size. Preconditioning was done in preconditioner of extruder at temperature 40°C and 10 to 25 % moisture content provided by steam. The extruder was operated at barrel temperatures between “140”, “145”, “150” and “155”°C for four different treatments T1, T2, T3 and T4 respectively. Due to high temperature treatment of barrel a laminate was formed along the barrel of extruder and moved towards the die of extruder under high pressure and emerged out of die in the form of a round shaped cylindrical extrudates of texturized vegetable protein. As the extrudates emerged from the die, it was cut into 10-30mm long pieces with a rotating knife. The samples of texturized vegetable protein were dried at 30-35°C for 30-45 min in a drier and stored in plastic bags at room temperature for further analysis.

Physical analysis

The expansion ratio of texturized vegetable protein was determined by measuring diameter of extrudates at several different locations along the strand of extrudates (Rayas et al., 1998). The bulk density was calculated by dividing the weight of extrudates by its volume presented by method of Okaka and Potter (1979). Water solubility index was determined from the amount of dried solids recovered by evaporating the supernatant, and was expressed as gram dried solids per gram of sample (Anderson et al., 1969). The Water absorption of texturized vegetable protein was measured by the centrifugation method of Vani and Zayas (1995). The water and oil absorption capacities were expressed as grams of water or oil bound per gram of the sample on a dry basis. The Hardness of the texturized vegetable proteins was determined by using TA.XT.PLUS, (Texture Analyser Stable Micro-Systems UK) (Veronica et al. 2006). Method of Krishna and Ranjhan (1981) with slight modification was used to estimate the Calorific Value (C.V) of the texturized vegetable protein by using Parr Oxygen Calorimeter. The pH of texturized vegetable protein was determined by pH meter model (WTW Series pH 720) by the method of Rhee et al. (2004).

Chemical assays of texturized vegetable protein

All the samples were analyzed for the moisture, ash, fat, protein and fiber contents according to their respective method Nos. 44- 15A, 08-01, 30-10, 46-10 and 32-10, given in AACC (2000).

Preparation of patties

The patties were prepared by the method as directed by Crowe et al., (2001). Texturized vegetable
protein was ground and hydrated. Then coarse ground beef was blended with the appropriate amount of hydrated TVP. The mixture of ground beef and TVP was then ground by passing through a meat grinder fitted with a 0.32-cm die plate, and ground mixture was held at 4°C until used to make patties. TVP based ground beef patties were formed by placing 48 g 50% TVP ground beef into a cylindrical mold and hand patting to a uniform thickness of 1.3 cm. The patties were held in refrigerator until cooked. Then the patties were cooked at 185°C for 3.5 min, flipped, and allowed to cook for an additional 2.5 min to an internal temperature of 70°C. The patties were allowed to cool to room temperature and then samples were taken for sensory evaluation.

Sensory evaluation of patties

The samples of TVP based patties were subjected to sensory evaluations conducted by a panel of judges from the staff and postgraduate students of National Institute of Food Science And Technology (NIFSAT). A 9-point hedonic scale (from 1=extremely disliked to 9=extremely liked) was used to determine the preference in color, flavor, taste, texture and overall acceptability according to the procedure described by Stone and Sidel (1998).

Statistical analysis

Data obtained was analyzed statistically as described by Steel et al., (1997). The data were interpreted by analysis of variance (ANOVA) using M-Stat C software package as described by Steel et al. (1997). ANOVA tested the significance of differences between samples at 5% level of significance. LSD test was used to determine the level of significance that existed between the mean values.

Results and Discussion

Physical characteristics of texturized vegetable protein

Physical tests and observations of extrudates actually describe some of their quality characteristics and its evaluation with respect to the consumer point of view. These parameters are of great importance as it determines the over all acceptability of the final product as these parameters are responsible to attract one’s eye towards product by enhancing its physical appearance and an appealing outlook besides the organoleptic properties. The mean values regarding the physical characteristics of texturized vegetable protein are given in Table 1

Expansion ratio (ER) of texturized vegetable protein

It is evident from the results that treatments (temperature) have significant effect on the expansion ratio of texturized vegetable protein. The expansion ratio of texturized vegetable protein varied from 1.85 to 1.92.

It is evident from the results that extrusion temperature significantly affected the expansion ratio of the texturized vegetable protein. The highest expansion ratio (1.92) was observed for highest temperature (155°C) while lowest extrusion temperature (140°C) gave lower value of expansion ratio for texturized vegetable protein (1.85). The results also make it very obvious that with gradual increase in temperature of barrel the expansion ratio increased with same rate. This showed that the Overall expansion increased linearly with increasing temperature to 155°C.

An increase in temperature resulted in an increase in expansion. Temperature was a dominant variable affecting macroscopic characteristics of extrudates. The different levels of temperature affected all macroscopic (expansion) properties of extrudates. A similar range of expansion ratio has also been reported for other pulses (peas, lentils) when extruded under similar conditions (Patil et al., 2007).

The results were also in accordance with the findings of Dogan and Karwe (2003). They observed that increase in barrel temperature show a positive linear effect on expansion ratio of the final product. Also by gradual rise in temperature there is gradual rise in expansion ration of the extrudates and this occurs to a certain level of temperature which is 168 °C. They suggested the existence of temperature plateau for expansion, between 150 and 170 °C depending on the type of food material. This phenomenon may be caused by excessive structure breakdown and starch degradation under high temperature which weakened the extrudates structure and therefore caused it to collapse. On the other hand the decreased expansion at high temperature could also occur. But at 155 °C there was gradual increase in expansion ratio of the texturized vegetable protein due to gelatinization of starch content of raw material and breakdown of protein bonding to optimum value.

The results were also in accordance with findings of Pe´rez et al. 2006. They observed that maximum expansion was produced with extrusion at 155 °C. This can be explained by the fact that when materials are forced through an extruder die their water content vaporizes, and the simultaneous vapour flash off expands their starch content, producing a porous, sponge-like structure in the extrudate. Extrude degree of expansion is closely linked to the size, number and distribution of air cells within the material.

Bulk density (BD) of texturized vegetable protein

It is evident from the results that treatments (temperature) have significant effect on the bulk density of texturized vegetable protein. The bulk density of texturized vegetable protein varied from 0.63 to 0.57g/L. It is evident from the results that extrusion temperature significantly affects the bulk density of the texturized
Table 1 Mean values for expansion ratio, bulk density, calorific value, pH, water absorption capacity, oil absorption capacity, water solubility index and hardness and breaking strength of of texturized vegetable protein

<table>
<thead>
<tr>
<th></th>
<th>T1 (140°C)</th>
<th>T2 (145°C)</th>
<th>T3 (150°C)</th>
<th>T4 (155°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expansion ratio</td>
<td>1.85c</td>
<td>1.88 b</td>
<td>1.89b</td>
<td>1.92a</td>
</tr>
<tr>
<td>Bulk density g/L</td>
<td>0.63a</td>
<td>0.61b</td>
<td>0.59 b</td>
<td>0.57c</td>
</tr>
<tr>
<td>Calorific value</td>
<td>4196 d</td>
<td>4199 c</td>
<td>4203 b</td>
<td>4207 a</td>
</tr>
<tr>
<td>pH</td>
<td>7.42a</td>
<td>7.43a</td>
<td>7.42a</td>
<td>7.42a</td>
</tr>
<tr>
<td>Water absorption</td>
<td>1.38c</td>
<td>1.41bc</td>
<td>1.42ab</td>
<td>1.45a</td>
</tr>
<tr>
<td>capacity g/L</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oil absorption</td>
<td>0.12c</td>
<td>0.17b</td>
<td>0.21a</td>
<td>0.24a</td>
</tr>
<tr>
<td>capacity g/L</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water solubility</td>
<td>2.02c</td>
<td>2.05bc</td>
<td>2.07ab</td>
<td>2.10a</td>
</tr>
<tr>
<td>index</td>
<td></td>
<td></td>
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<tr>
<td>Hardness and</td>
<td>25.6a</td>
<td>20b</td>
<td>17c</td>
<td>16.03c</td>
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<tr>
<td>breaking strength</td>
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vegetable protein. The highest bulk density (0.63 g/L) was observed for lowest temperature (140°C) while highest extrusion temperature (155°C) gave lower value of bulk density of texturized vegetable protein (0.57 g/L). It is also clear from results that bulk density decreases with gradually increase in temperature. During extrusion bulk density was influenced by temperature and it decreased with increasing temperature. If expansion ratio increased it would be logical to assume that bulk density would decrease, under similar conditions but bulk density increased abruptly when temperature increased from 130 to 140 °C. This could be due to the effect of high temperatures on viscosity and starch degradation resulting in less expansion.. Bulk density and expansion are also related to starch gelatinization. (Rayas et al., 1998). According to these authors an increase in gelatinization increased expansion and decreased bulk density.

There is also relationship between bulk density and expansion ratio. When temperature of barrel is increased the expansion ratio rises to certain degree of temperature while the bulk density of extrudates show the negative course of action in this regard. Bulk density also describes the degree of expansion undergone by the melt as it exits the extruder. The sectional expansion ratio considers only in the direction perpendicular to extrudates flow, while bulk density considers expansion in all directions (Altan et al., 2008).

Calorific value of the texturized vegetable protein (cal/gm)

Calorific value means the heat/energy generated by the product when burned/digested. Every product has its specific calories and texturized vegetable protein exhibited results regarding calorific value on evaluation by bomb calorimeter. It is evident from the results that treatments (temperature) have significant effect on the calorific value of texturized vegetable protein. The calorific value of texturized vegetable protein varied from 4196 to 4207. It is evident from results that extrusion temperature highly significantly affects the calorific value of the texturized vegetable protein. These results are in accordance with the findings Fuhrmeister and Meuser (2003). They stated that by increasing the barrel
Water absorption characteristics represent the ability of a (WAC) of different cereals ranged from 1.33 to 1.47 g/g. That water absorption capacity increased gradually with relatively increased water absorption capacity (1.38 g/g). It is also clear from results that extrusion temperature (140°C) gave lower value of water absorption capacity of texturized vegetable protein. The highest water absorption capacity (1.45 g/g) was observed for highest temperature (155°C) while lowest extrusion temperature (140°C) gave lower value water absorption capacity (1.38 g/g). It is also clear from results that water absorption capacity increased with gradually increase in temperature. The water absorption capacity (WAC) of different cereals ranged from 1.33 to 1.47 g/g. Water absorption characteristics represent the ability of a product to associate with water under conditions where water is limiting (Singh, 2001). The results are in accordance to the findings of Noguchi, 1889 they proposed that when temperature of barrel of extruder is raised there is relative increase in water absorption capacity of the texturized vegetable protein. This is because water absorption capacity of extrudates mainly depends on temperature of barrel. When temperature of barrel is raised the melt viscosity of food mix is decreased and layer formation of fiber is enhanced. In this way protein aggregation and cross linking is enhanced prevention the subsequent water absorption and facilitating the formation of more laminating structure of material being extruded and more solidification after passing through die. This enhances the water absorption capacity of extrudates on rehydration. The results of present study also matched with study of Hayashi et al. 1992. Gujska and Khan (1990) studied the effect of temperature on WAC on high starch fractions of pinto and navy beans during extrusion. WAC increased from 3.0 (110°C) to 4.0 (132°C) for pinto beans but could not be evaluated at 150°C because the extrudates burned. In the present study water absorption increased to 150°C but this is quite rational as water absorption capacity varies at different temperatures for different types of materials being extruded. This variation is evident from the work of Gujska and Khan (1990) who reported in same study that navy beans exhibited a maximum WAC (4.0) at 132°C and lower values (3.83) at 150°C.

It is evident from the results that treatments (temperature) have significant effect on the oil absorption capacity of texturized vegetable protein. The oil absorption capacity of texturized vegetable protein varied from 0.12 to 0.24 g/g. It is evident from results that extrusion temperature significantly affects the oil absorption capacity of the texturized vegetable protein. The highest oil absorption capacity (0.24 g/g) was observed for highest temperature (155°C) while lowest extrusion temperature (140°C) gave lower value of oil absorption capacity of texturized vegetable protein (0.12 g/g). It is also clear from results that oil absorption capacity increases gradually relative increase in barrel temperature. It is generally observed that oil absorption during deep fat frying is essentially a quantitative water replacement process where higher initial moisture results in greater oil absorption during frying. Such a relationship has been demonstrated in extrusion formed deep fat fried tapioca chips (Nair et al., 1996) and in tortilla chips (Moreira et al., 1997). Gautam et al. (1987) using a staining procedure has demonstrated that oil uptake by a fried snack occurs primarily in areas that exhibit moisture loss as extrusion causes lowering of moisture content so oil absorption capacity is enhanced by increasing temperature. Oil absorption varied significantly, suggesting that extrusion variable temperature critically influences oil absorption.

**pH of texturized vegetable protein**

It is evident from the results that treatments (temperature) have non-significant effect on the pH of texturized vegetable protein. The pH of texturized vegetable protein extrudates varied from 7.42 to 7.43. It is evident from the results that extrusion temperature non-significantly affects the pH of the texturized vegetable protein. The highest pH (7.43) was observed for high temperature (155°C) while low extrusion temperature (140°C) gave low value for texturized vegetable protein pH (7.42). It is clear from the results that pH does not decrease much but a minute decrease is observed which is negligible and this decrease is not due to temperature change gradually because at low temperature (140°C) the value is 7.42 and at highest temperature (155°C) the value is same but at temperature 140°C the value is a little bit high 7.43 which shows that minute change is not due to temperature rising. These results are in accordance with the findings of Riaz, (2000) he found that by increasing barrel temperature there was no significant effect on the pH of extrudates. He observed the results from soy extrudates and found that pH did not change significantly due to change in temperature but a minute change was there in extrudates of different temperatures. So it is clear from observations that pH of the extrudates of different treatments (temperatures) was same.

**Water and oil absorption of texturized vegetable protein**

It is evident from the results that treatments (temperature) have highly significant effect on the water absorption capacity of texturized vegetable protein. The water absorption capacity of texturized vegetable protein varied from 1.38 to 1.47 g/g. It is evident from results that extrusion temperature significantly affects the water absorption capacity of the texturized vegetable protein. The highest water absorption capacity (1.45 g/g) was observed for highest temperature (155°C) while highest extrusion temperature (140°C) gave lower value water absorption capacity (1.38 g/g). It is also clear from results that water absorption capacity increased with gradually increase in temperature. The water absorption capacity (WAC) of different cereals ranged from 1.33 to 1.47 g/g. Water absorption characteristics represent the ability of a product to associate with water under conditions where...
According to Kinsella (1976) more hydrophobic proteins show superior binding of lipids, implying that non-polar amino acid side chains bind the paraffin chains of fats. The OAC of most cereals ranged from 1.05 to 1.17 g/g.

**Water solubility index (WSI) of texturized vegetable protein**

It is evident from the results that treatments (temperature) have non significant effect on the water solubility index of texturized vegetable protein. The water solubility index of texturized vegetable protein varied from 2.02 to 2.10. It is evident from results that extrusion temperature significantly affects the water solubility index of the texturized vegetable protein. The highest water solubility index (2.10) was observed for higher temperature (155°C) while at lowest extrusion temperature (140°C) gave lower value for water solubility index (2.02). It is also clear from results that water solubility index decreases with increase in temperature. WSI increased significantly with increasing temperature, which may be related to starch depolymerization at higher temperatures, reducing molecular length of amyllose and amyllopectin chains. These results confirmed those of Anderson et al. (1969) who had extruded bean and sorghum. Also Gujska and Khan (1990) reported a significant increase in WSI with increasing extrusion temperature. However, Gujska and Khan (1990) found that WSI decreased significantly with increasing moisture in extrusion of pinto bean flour from 35.3 at 20% feed moisture to 21.1 at 30% feed moisture. Moreover, increasing the rice flour level from 0% to 25% decreased the water solubility index (WSI) of extrudate significantly. However increasing the flour level from 25% to 50% caused a slight decrease in the water solubility index (WSI) of extrudates but not significantly. (Anderson et al., 1969).

**Hardness and Breaking strength of texturized vegetable protein**

It is evident from the results that treatments (temperature) have highly significant effect on the hardness and breaking strength of texturized vegetable protein. The hardness and breaking strength of texturized vegetable protein varied from 16.03 to 25.6 N. It is evident from results that extrusion temperature highly significantly affects the hardness and breaking strength of the texturized vegetable protein. The highest hardness and breaking strength (25.6N) was observed for lowest temperature (140°C) while highest extrusion temperature (155°C) gave lower value of hardness and breaking strength of texturized vegetable protein (16.03N). It is also clear from results that hardness and breaking strength decreases with gradually increase in temperature. Peak values of graphs as shown in Figures showed the maximum force required to break the product being analyzed for textural properties so called hardness and breaking strength. These results match with the results of Chinnaswamy and Hanna, (1988) they stated that decreasing hardness and breaking strength was related to decrease in bulk density of the extrudates with increasing barrel temperature, resulting in a less material in the area being tested. A more expanded product may have a weaker structure or lower mechanical strength. Hardness and breaking strength of extrudates was significantly affected by changing the barrel temperature besides other variables. Barrel temperature had significant quadratic effects on extrudates hardness and breaking strength. Other independent variables like feed moisture also affect the hardness of the extrudates. Hardness and breaking strength decreased with decreasing feed moisture content. The hardness and breaking strength of extrudates ranged from 18 to 34 N as elaborated by Veronica et al, 2006. Low hardness and breaking strength which is also a favored property of extrudates was observed at high temperature. The hardness and breaking strength of expanded extrudates is a perception of the human being and is associated with expansion and cell structure of the product (Veronica et al., 2006).

**Chemical analysis of texturized vegetable protein**

The extrudates of texturized vegetable protein were evaluated for their chemical properties. The mean values for of different constuttes regarding chemical composition of texturized vegetable protein are given in Table 2.

**Moisture contents of texturized vegetable protein**

The moisture content of texturized vegetable protein varied from 9.92 to 9.20%. It is evident from the results that extrusion temperature significantly affected the moisture content of the texturized vegetable protein. The highest moisture content (9.92%) was observed for lowest temperature (140°C) while highest extrusion temperature (155°C) gave lower value of moisture content of texturized vegetable protein (9.92%). It is also clear from the results that moisture content decreases with gradually increase in temperature. The results regarding the moisture content were in accordance to the study of Ding et al, (2006). They proposed that the moisture content is affected as we change the temperature of barrel. Moisture content (the quantitative determination of total water content) of the final product determines the stability and quality of food material as moisture content of the final product affects different nutritional as well as organoleptic properties of food and most importantly it determines the texture of product.

**Protein contents of texturized vegetable protein**

The crude protein of texturized vegetable protein varied from 22.39 to 22.33%. It is evident from the results that extrusion temperature significantly affects the
crude protein of the texturized vegetable protein. The highest crude protein (22.39%) was observed for lowest temperature (140°C) while highest extrusion temperature (155°C) gave lower value of crude protein for texturized vegetable protein (22.33%). It is also clear from results that crude protein decreases to very minute degree with gradual increase in barrel temperature. This was due to high temperature of barrel that protein molecules were readily denatured and bonding was disrupted and re-bonding occurred as high temperature facilitated the formation of new bonding and denaturing certain enzymes and pigments that create obnoxious flavor and enhance certain ant-nutritional characteristics. Due to denaturation of these enzymatic proteins there existed a very minute decrease of protein content in final product as proposed by Riaz, 2000. It showed that by increasing barrel temperature the protein content of extrudates decreased but to very minute extent. The results were in accordance to the findings of the Riaz, 2000. He observed that in general as the amount of protein in the extrudates increased, expansion ratio decreased and color of final product also changed. This is because the expansion ratio is due to starch content of raw material, more the starch content more will be the expansion ratio. But in case of protein there are different processes takes place during extrusion cooking process the most important is denaturation of protein molecules. It did not mean that protein is totally denatured but due to high temperature and pressure and shearing effect material is intermingled within the extruder and resultantly bonding of protein molecules is disrupted and new bonding occurs that leads towards formation of new product when passing through die of small aperture and which is of modified form of protein and is more desirable in view of modern needs of time (Riaz, 2000).

**Ash contents of texturized vegetable protein**

The ash content for texturized vegetable protein remained nearly same as the after different treatments of temperature during extrusion. It is evident from the results that treatments (temperature) have non significant effect on the ash content of texturized vegetable protein. The ash content of texturized vegetable protein varied from 3.3 to 3.29%. It is evident from results that extrusion temperature none significantly affects the ash content of the texturized vegetable protein. The highest ash content (3.3%) was observed for lowest temperature (140°C) while highest extrusion temperature (155°C) gave lower value of ash content for texturized vegetable protein (3.29%). It is clear from the results that ash content did not decrease much but a minute decrease was observed which is negligible. This shows that extrusion cooking results in considerable retention of nutrients like certain minerals such as calcium, iron and zinc. This is attributed to a high-temperature, short-time process of extrusion cooking, thereby yielding a better product. The results are in accordance with the findings of (Ding et al., 2006).

**Fat contents of texturized vegetable protein**

It is evident from results that treatments (temperature) have non significant effect on fat contents of texturized vegetable protein. The fat content of texturized vegetable protein varied from 1.63 to 1.66%. At highest temperature (155°C) value of fat content was 1.66 % and at lowest temperature 140°C value was 1.66% as well. It is evident from results that barrel temperature during extrusion non significantly affects the fat content of texturized vegetable protein. Bredie et al. 2002 reported that the addition of fat during extrusion decreases to very minute degree due to degree of gelatinization of starch content of material and due to decrease of the barrel temperature caused by the lubricating effect fat. Fat also decreases conversion of starch content during extrusion by preventing severe mechanical breakdown of the starch granules by rotating screw and preventing water from being absorbed by starch. Reduced starch conversion/gelatinization ultimately results in decreased expansion. The results showed that the fat content of texturized vegetable protein remained same by varying temperature of barrel. As the temperature of barrel increased there is no significant difference in fat content of texturized vegetable protein but to a negligible degree. Fat portion of material is also utilized to lubricate the screw and barrel and imparts a characteristic flavor on extrusion cooking. This also showed that extrusion cooking results in considerable retention of fat in the extrudates. Fat level used for extrusion in present study was ideal because for production of texturized vegetable protein value 0.5 to 6.5 is recommended (Riaz, 2000).

**Fiber contents of texturized vegetable protein**

The crude fiber of texturized vegetable protein varied from 2.10 to 2.07%. It is evident from results that extrusion temperature none significantly affects the crude fiber of the texturized vegetable protein. These results showed that application different level of barrel temperature non significantly affected the crude fiber content of texturized vegetable protein. The highest crude fiber (2.10%) was observed for lowest temperature (140°C) while highest extrusion temperature (155°C) gave lower value of crude fiber of texturized vegetable protein (2.07%). This shows that by increasing the temperature there is no significant difference among different treatments and final product. All treatments showed almost similar results. As extrusion is a high temperature and short time cooking process which let the certain contents of material less affected and ensures the retention of these nutritional components. The earlier
traditional cooking processes showed that the crude fiber significantly increased by cooking treatments but these cooking methods were simple and traditional and did not involved any controlled environment like levels of temperature and keeping some other parameters constant. This increase could have been due to protein-fiber complexes formed after possible chemical modification induced by the soaking and cooking of dry seeds also there was effect of antinutritional factors (Bressani, 1993). But extrusion cooking affects less due to short time and high temperature treatment. The antinutritional factors are destroyed and certain other pigments and components that cause obnoxious flavor and taste are also evaporated through an opening during extrusion cooking the results of all treatments showed less considerable difference on treating at varying level of temperature (Riaz, 2000).

Sensory evaluation of texturized vegetable protein

The results regarding sensorial characteristics of texturized vegetable proteins based patties are presented in Table 3.

<table>
<thead>
<tr>
<th>Color of texturized vegetable protein patties</th>
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</table>
| Color is an important characteristic of a product with respect to its sensory attributes and it appeals consumer attraction towards itself. It is evident from the results that treatments (temperature) have significant effect on color parameter of texturized vegetable protein. The values of color of texturized vegetable protein based patties varied from 6.33 to 6.41. It is evident from results that extrusion temperature highly significantly affects the sensory evaluated color of the texturized vegetable protein. The highest color value (6.41) was observed for highest temperature (155°C) while lowest extrusion temperature (140°C) gave lower value of color for texturized vegetable protein (6.33). It is also clear from results that sensory evaluated color increases with gradual increase in temperature. The results are in accordance to the findings of Rokey (2000) who found that color changes during the extrusion process, can provide important information regarding the degree of thermal treatment. By applying different levels of temperature of barrel during extrusion cooking create a varying degree of color of final product. This is because when temperature is high, cooking is done properly and development of color occurs to optimized degrees and hence imparting color to final product which is desirable and acceptable by consumer. But when temperature is low the color development process is slow due to availability of insufficient temperature requirement. Analysis of variance indicated that the effect of temperature on moisture content was to greater extent and as moisture content is important in color development so it affected the color development in final product of extrusion (Ding et al., 2006). So increasing temperature the bond disruption process is also enhanced and hence a positive effect on color parameter of product was observed in texturized vegetable protein. A higher temperature would increase product internal temperature, which promotes the browning reactions in sugar content of raw material and due to these browning reactions a characteristic color was produced. But the lower temperature would decrease the heating of internal composition of the dough inside the extruder and resulted in lighter products. (Altan et al., 2008). The results were also similar to the study of Badrie and Mellowes (1991). They proposed that when barrel temperature is increased during extrusion cooking there is relative increase in color intensity of the extruded material. When temperature is increased there is change in color intensity due to browning reactions of sugar content of the material. In the end color intensity is enhanced. The results of present study were similar to early findings and there was an increase in color value with gradual rise of temperature which is desirable.

Flavor of texturized vegetable protein patties

<table>
<thead>
<tr>
<th>Flavor of texturized vegetable protein patties</th>
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<tbody>
<tr>
<td>The results regarding flavor characteristics of texturized vegetable proteins based patties are presented in Table 4.</td>
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</tbody>
</table>
It is evident from the results that treatments (temperature) have significant effect on the flavor of texturized vegetable protein. The values of flavor of texturized vegetable protein based patties varied from 5.86 to 5.99. It is evident from the results that extrusion temperature significantly affects the sensory evaluated flavor of the texturized vegetable protein. The application of gradual rise in temperature left positive affect on flavor of TVP. The highest observed value of flavor of texturized vegetable protein (5.99) was for highest temperature (155°C) while lowest extrusion temperature (140°C) gave lower value of flavor for texturized vegetable protein (5.86). It is also clear from results that sensory evaluated flavor increases with gradually increase in barrel temperature of extruder during extrusion process. These results match with the results given by Bhandari et al., (2001) he reported that by increasing temperature of extrusion flavor is developed in extruded product due to activation of flavor producing compounds at higher temperature. The results are in accordance to the findings of Kadlec, 2000. He proposed that flavor is enhanced by increasing barrel temperature due to presence of sugar contents in raw material and when this sugar content is heated at high temperature complex chemical reactions occur and resultantaly a characteristic flavor is produced. Also when heated at high temperature certain obnoxious flavor is degraded but degree of formation of new flavor is more than this degradation. The results of present study showed that with increase in barrel temperature there was significant increase in flavor of texturized vegetable protein.

Taste of texturized vegetable protein patties

It is evident from the results that treatments (temperature) have significant effect on taste of the texturized vegetable protein. These values varied from 6.87 to 6.97. It is evident from results that extrusion temperature significantly affected the taste of the texturized vegetable protein. The highest sensory evaluated taste (6.97) was observed for highest temperature (155°C) while lowest extrusion temperature (140°C) gave lower value for of sensory evaluated taste of texturized vegetable protein (6.87). These results make it very clear that by gradual increase in temperature during extrusion process the taste of extruded material enhanced as it is evident in $T_a$. The sensory evaluated taste has significant difference between the extrudates obtained from different treatments. The results matched with work of Rampersad et al., (2003). He proposed that when temperature of processing technique is increased to a certain degree it produce a desirable taste in the product as its human perception by senses to observe the taste of product. But if temperature is low and cooked food has not desirable taste characteristics due to under cooking. This is because when temperature is raised in extrusion cooking it results in cooking of product and removing and disruption of certain components which affect the taste of product in negative way. In this way in present study application of 155°C in $T_a$ showed the value of the most acceptable taste. In this way it is very obvious that by increasing temperature gradually taste value increased significantly.

Texture of texturized vegetable protein patties

It is evident from results that treatments (temperature) have significant affect on sensory evaluated texture of texturized vegetable protein. These values varied from 5.85 to 6.15. It is very clear from results that extrusion temperature significantly affects the texture of sensory evaluated texture of texturized vegetable protein. The highest value of sensory evaluated texture (6.15) was observed for highest temperature (155°C) while lowest extrusion temperature (140°C) gave lower value for texture of product (5.85). This showed that with gradual increase in temperature of barrel texture was positively affected to a certain limit of temperature beyond which texture has not same results. The results were in accordance to the findings of Lin et al., 2000. According to him by increasing the barrel temperature the maximum bond disruption occurs and results in formation of more homogeneous laminate along barrel which produce more compact mass and hence imparting better textural characteristics. The results matched with earlier findings of Little and Hills, 1978. They proposed that by increasing the barrel temperature during extrusion of chickpea there was gradual increase in sensory evaluated texture of the product in all ratios.

Overall acceptability of texturized vegetable protein patties

The overall acceptability of texturized vegetable protein based patties of different treatments varied from 5.95 to 6.35. It is evident from the results that variation in barrel temperature of extruder during extrusion significantly affected the overall acceptability of the final product. The highest value of overall acceptability (6.35) was observed for highest temperature (155°C) while lowest extrusion temperature (140°C) gave lower value for overall acceptability (5.95). It is also clear from results that overall acceptability increases with gradually increase in temperature to 155°C. Guy (2001) besides elaborating effect of die also proposed that when temperature of barrel is gradually increased there is positive effect on the extruded material from overall acceptability point of view of the final product. This is because the overall acceptability of product is directly related with other sensory attributes. When other sensory characteristics show positive value with increase in temperature then affect of temperature is also significant on overall acceptability of the final product to be
evaluated for overall acceptability. If temperature is low the material will not be in laminating appearance and hence causing a hindrance in flow along the barrel of extruder. The results were in accordance to the findings of the Riaz, 2000. He proposed that by increasing temperature of barrel during extrusion for formation of texturized vegetable protein the sensory parameters color, flavor, texture and taste showed a linear trend as depicted in statically analysis so as over all acceptability is directly related with sensory attributes hence it is also significant with rise of temperature.

Conclusion

The research work was carried out to prepare texturized vegetable protein using indigenous source of protein by process of extrusion cooking. Different ranges of temperature were used to ensure the formation of product with more acceptable attributes. This temperature range was 140, 145, 150 and 155 °C. Effect of temperature variation was evaluated in different physical, nutritional and sensory characteristics of the final product. As for as the effect of temperature on physical attributes is concerned it showed a linear relationship between temperature and expansion ratio with values ranging 1.85, 1.88, 1.89 and 1.92 for four treatments T1, T2, T3 and T4 respectively. T4 was most suitable value of temperature for maximum expansion. But for bulk density results were declining with increase in temperature having values ranging 0.63g/L, 0.61g/L, 0.59g/L and 0.57g/L for four treatments T1, T2, T3 and T4 respectively. The results for fat content and ash content of texturized vegetable protein were non significant. Moisture content was decreased by increasing barrel temperature of extruder. The protein of final product showed results ranging 22.39, 22.360, 22.34 and 22.33 for four treatments respectively. This showed by increasing barrel temperature there is a minute decrease in protein content as certain enzymes and proteinous pigments having obnoxious flavor are disrupted during extrusion cooking. Then TVP based patties were made and product was evaluated for sensory properties which include color, flavor, taste, texture and overall acceptability. The color, flavor, taste, texture and overall acceptability showed increasing trend with rise in temperature. The results for color showed trend ranging 6.33, 6.37, 6.39 and 6.41 and flavor was in range of 5.86, 5.91, 5.95 and 5.99. At low temperature treatment of 140°C value of taste was 6.87 and at high temperature of 155 °C the value was 6.97. This showed that by increasing temperature cooking properties of dough’s improved with better color, flavor and taste. Similar results were observed for texture and overall acceptability. The other attributes of texturized vegetable protein were evaluated like water solubility index, water and oil absorption and hardness and breaking strength. The results for water solubility index were 2.02, 2.05, 2.07, and 2.10 for four treatments T1, T2, T3 and T4 respectively. The water absorption capacity ranged 1.38g/g, 1.41g/g, 1.42g/g and 1.45g/g for four different levels of temperature. This showed an increasing trend which means by increasing barrel temperature proteinous and water absorption capacity is increased. The results for oil absorption capacity were also in almost similar fashion. Hardness and breakability showed a linear declining trend with rise in temperature and mean values ranged from 35.6 N to 16.03 N. Due to all attributes close to texturized vegetable protein made of soybean, the product was approved by sensory panel for use as color, texture and taste fulfilled the desired characteristics.

References


Table 3 Mean values for sensory evaluation of texturized vegetable protein

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Color</th>
<th>Flavor</th>
<th>Taste</th>
<th>Texture</th>
<th>Overall acceptability</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1 (140°C)</td>
<td>6.33d</td>
<td>5.86d</td>
<td>6.87c</td>
<td>5.85d</td>
<td>5.95d</td>
</tr>
<tr>
<td>T2 (145°C)</td>
<td>6.37c</td>
<td>5.91c</td>
<td>6.90c</td>
<td>5.89c</td>
<td>6.09c</td>
</tr>
<tr>
<td>T3 (150°C)</td>
<td>6.39b</td>
<td>5.95b</td>
<td>6.93b</td>
<td>6.06b</td>
<td>6.16b</td>
</tr>
<tr>
<td>T4 (155°C)</td>
<td>6.41a</td>
<td>5.99a</td>
<td>6.97a</td>
<td>6.15a</td>
<td>6.35a</td>
</tr>
</tbody>
</table>

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