INTRODUCTION

The total production of vegetables and melons was estimated as 941.1 million tonnes in the world during the year 2009 (FAO statistics, 2009). The food processing industry produces large quantities of waste co-products. About 27.941 million tonnes of food waste from the food processing industry are produced in the European Union only every year (Eurostat data, 2006).

Fruit and vegetable wastes are inexpensive, available in large quantities, characterized by a high dietary fibre content resulting with high water binding capacity and relatively low enzyme digestible organic matter (Serena & Knudsen, 2007). Dietary fibre concentrates from vegetables showed a high total dietary fibre content and better insoluble/soluble dietary fibre ratios than cereal brans (Grigelmo-Miguel and Martin-Beloso, 1999). Due to the high dietary fibre content, the co-products could be used to change physicochemical properties of diets. A number of researchers have used fruits and vegetable by-products such as apple, pear, orange, peach, blackcurrant, cherry, artichoke, asparagus, onion, carrot pomace (Grigelmo-Miguel and Martin-Beloso, 1999; Ng et al., 1999; Nawirska and Kwasnievska, 2005) as sources of dietary fibre supplements in refined food.

The carrot (Daucus carota) is a root vegetable, usually orange, purple, red, white or yellow in color, with a crisp texture when fresh. The total production of carrot & turnips was estimated as 28 million tonnes in the world during year 2009 (FAO statistics, 2009). It is a rich source of β-carotene and contains other vitamins,
like thiamine, riboflavin, vitamin B-complex and minerals (Walde et al., 1992). Carrot is also an excellent source of calcium pectate; an extraordinary pectin fiber that has the cholesterol lowering properties. It has a property to reduce the risk of high blood pressure, stroke, heart disease and some type of cancer (Bakhru, 1993).

The carrot is mainly consumed as raw, converted to juice drink, used as salads, cooked as vegetable dish, used to make sweet dishes. Fruit and vegetable juices have become important in recent years due to overall increase in natural juice consumption as an alternative to the traditional caffeine containing beverages such as coffee, tea, or carbonated soft drinks (Kaur et al., 2009). Carrot juice has particularly high content of pro-vitamin A (β carotene) and is also high in B complex vitamins and many minerals including calcium, copper, magnesium, potassium, phosphorus, iron and folic acid.

Carrot pomace is a by-product obtained during carrot juice processing. The juice yield in carrots is only 60-70%, and even up to 80% of carotene may be lost with left over carrot pomace (Bohm et al., 1999). As the fiber-rich pomace is available in large quantity during juice production, it is worth exploiting the carrot insoluble fiber-rich fractions (IFRF) as a promising hypocholesterolemic ingredient to fulfill the increasing demand of functional ingredients in developing fiber-rich food products. It was reported by the researchers that the incorporation of cellulose and IFRF into the fiber-free diet significantly reduced the serum total cholesterol levels by 17.3 and 33.5%, respectively (Hsu et al., 2006). It also has good residual amount of all the vitamins, minerals and dietary fibre. So far the left over pomace, received after juice extraction of carrots, does not find proper utilization. Moreover, vegetable pomace
has become a source of environmental problem. The carrot pomace is quite perishable as it contains about $88 \pm 2\%$ of moisture.

Drying or dehydration is the useful means to increase the shelf life of perishable food for further use (Roberts et al., 2008). Drying of materials having high moisture content is a complicated process involving simultaneous heat and mass transfer (Yilbas et al., 2003). The materials are dried using several techniques but thin layer drying is popular due to faster rate in comparison to other and minimum loss of nutrients.

Drying characteristics of apple pomace (Wang et al., 2007), grape seeds (Roberts et al., 2008), cocoa (Hii et al., 2009), garlic (Fernando et al., 2008) have been reported. Hot air oven drying of carrot pomace was reported by Upadhyay et al. (2008) in a hot air oven tray dryer without the consideration of air velocity. However, no published detailed information is available on hot air drying of thin layer carrot pomace.

The present investigation was primarily focused on the thin-layer drying characteristics of carrot pomace in a forced convective dryer and modelling the air drying process of carrot pomace over a temperature range of 60 to 75°C at air velocities of 0.5, 0.7 and 1.0 m/s. In addition, the effective diffusivities and activation energy in the convective drying process of carrot pomace were also planned to be calculated.

The dried carrot pomace has $\beta$ carotene and ascorbic acid in the range of 9.87 to 11.57 mg and 13.53 to 22.95 mg per 100 g respectively (Upadhyay et al., 2008). A promising way is to store the carrot pomace in dried form and utilize in the development of bakery products specifically extrudates, which are becoming more
popular than other bakery products in ready to eat food category.

Rice is grown as a monocarpic annual plant, in tropical areas. The edible seed is a grain (caryopsis) 5–12 mm long and 2–3 mm thick. Rice is a cereal foodstuff which forms an important part of the diet of many people worldwide, especially in tropical Latin America, and East, South and Southeast Asia, making it the second-most consumed cereal grain. Rice provides more than one fifth of the calories consumed worldwide by humans.

India is the second largest producer of paddy. The country produced 131.27 million tonnes in 2009 (FAO statistics, 2009). Paddy is mainly consumed in the form of rice obtained from primary processing. Paddy contains 20-25% husk, (including about 2% trash), 6% bran, and 75% rice (2% of the rice is very small pieces, brewer’s rice, and fines). The rice portion can have varying percentages (5-8%) of broken kernels which accounts 4.92 – 7.87 million tonnes.

The processing of paddy to rice involves the milling by using hullers, shellers and modern rice mills (>50%). The by-products from the hullers do not have much option to convert to value added products but to use as animal feed. The sheller and modern rice mills generate by-products, which have good option for utilization. The main by-products of rice mills are rice broken, husk and bran, do not have mass acceptability in the country. Husk is being used for generating steam hard board etc. Rice bran is mainly used for oil extraction; and the oil is popularly known as rice bran oil (RBO). Broken rice, possibly due to non-availability of technology for its conversion to value added products and development of taste and social consideration, are used in flour form in traditional recipes or used as animal feed. There are no major
industrial processes for effective utilization of broken rice, so there is scope for the research which utilizes the broken rice.

Red gram, also called as pigeon pea, ranks sixth among pulses production in the world and is the major legume crop. Average world production of red gram is 3.49 million tonnes in 2009 (FAO statistics, 2009). India is the largest producer of red gram and contributes more than 75% of world production and is also major consuming country constituting 90%.

Red gram is the second largest pulse crop in India accounting about 20 percent of total pulse production. It is a protein rich pulse and contains about 22 percent protein, which is almost three times that of cereals. Red gram supplies a major share of protein requirement of vegetarian population of the country. It is mainly consumed in the form of split pulse i.e. Dhal, which is an essential supplement of cereal based diet. Red gram is a valuable source of protein, minerals and vitamins and occupies a very important place in human nutrition in many developing countries like India (Singh, 1988). The method of dehulling of legumes significantly affects the formation of broken and powdered particles and in the case of red gram it varies between 9–24.6% (1.26 – 3.44 million tonnes) for broken and 5.5–6.1% (0.77 – 0.854 million tonnes) for powder (Singh et al., 1992). Pulse powder is a by-product of milling process which has a high protein content (22%) similar to dhal and easily available at relatively lower cost as compared to red gram pea dhal.
It can be observed from the Table 1.1 that rice and pulse are good source of carbohydrate and energy, whereas carrot is the good source of vitamin A and vitamin C. The protein content of the pulse is higher than the remaining two. The combination of above three may be useful for the study to make a blended extruded product, which should be of high energy, protein, dietary fiber and vitamins.

Extrusion cooking is a modern high-temperature short-time (HTST) processing technology. It offers several advantages over other types of cooking processes, such as faster processing times and significant reduction in energy consumed, which consequently results in lower prices for the final products. Extruders can be used for a wide range of traditional (conventional) food products, as well as in the production of numerous new products like cereal baby food, confectionery, breakfast cereals, snack foods, bakery products, flavors, pastas, pet food and meat products. An extruder represents a very complex bioreactor in which,
various types of raw food materials with different moisture contents and consistencies are treated under high temperatures, short residence times, high pressures and very strong shear forces. Shihani et al. (2006) used artificial neural networks are a powerful tool for modeling of extrusion processing of food materials.

In the food industry, the following operations take place during raw-material processing by extrusion: gelation, extrusion cooking, molecular disintegration, sterilization, mixing, shaping and expansional drying. In the course of conveying the raw material through the extruder by screw-turning, mechanical energy is created and turned into heat, which is transmitted to the raw material. The raw material is thus converted to a highly elastic mass which is extruded through a die (Chinnaswamy, 1993).

In warm extrusion, cooking temperatures lie within 120–180°C, and pressures are between 12 and 25MPa. The barrel and dies are cooled or heated as required to maintain the desired temperature. A HTST procedure is one which uses short residence time, high temperature, high pressure, large shear forces and intensive mixing (Zheng and Wang, 1994). Under these conditions, the dipolymers in the raw material are subject to protein de-naturation, starch glue formation and plasticization of the complete volume. The evolved plasticized volume expands through the die due to rapid fall in pressure, to form an extrudate with characteristic properties. These properties are very different from those of the starting raw material (Cai et al., 1995).

The effects of extrusion cooking on the physicochemical characteristics and microstructure of cell walls on onion waste were investigated by Ng et al. (1999). They found that extrusion cooking increase the solubility of pectic polymers and hemicelluloses accompanied by an increase in swelling of the cell-wall material.
Later, the properties of fibre components in orange pulps using extrusion technology was modified by Larrea (2005) and reported that extrusion conditions decreased insoluble dietary fibre and increased soluble fibre. The incorporation of cauliflower trimmings into ready-to-eat expanded products up to 10% level was suggested by Stojceska et al. (2008). Altan et al. (2008, 2008a) processed the blends of barley flour and tomato pomace; barley flour, grape pomace, corn flour and tomato pomace in a co-rotating twin-screw extruder. Limited information is available on extrusion processing of carrot by-products.

The objective of this study was to incorporate carrot by-products as a source of dietary fibre into ready-to-eat snacks. Upadhyay (2008) reported the use of carrot pomace, gram flour and rice flour based formulation for extrusion studies. However, the range of process variable was too wide. Literature survey indicates that no detailed study on the incorporation of carrot by-products into extruded products has been published.
JUSTIFICATION

India is the 2\textsuperscript{nd} largest producer of paddy and more than 70\% of produced paddy is processed through modern rice mills which produce 71\% of rice, 20\% of husk and 5-8\% of rice broken and 6-7\% of rice bran. In India, mostly rice broken are used as poor man’s staple food which is having the same nutritional significance as that of whole rice.

India is the largest producer of red gram and contributes more than 75\% of the world’s production. The production of red gram is 2.0 million tonnes, which is mostly processed by modern dehulling machines along with pretreatment in \textit{dhal} mills. The production of \textit{dhal} powder is about 2-3\%, which is highly nutritive (containing same proportion of protein as that of \textit{dhal}). This byproduct is thrown away or utilized as animal feed.

The carrot (\textit{Daucus carota}) is a root vegetable, usually orange, purple, red, white or yellow in color, with a crisp texture when fresh. The total production of carrot & turnips was estimated as 28 million tonnes in the world during year 2009 (\textit{FAO} statistics, 2009). It is a rich source of β-carotene and contains other vitamins, like thiamine, riboflavin, vitamin B-complex and minerals (\textit{Walde et al.}, 1992). Carrot pomace is a by-product obtained during carrot juice processing. The juice yield in carrots is only 60-70\%, and even up to 80\% of carotene may be lost with left over carrot pomace (\textit{Bohm et al.}, 1999). It also has good residual amount of all the vitamins, minerals and dietary fibre. So far the left over pomace, received after juice extraction of carrots, does not find proper utilization.

So, in the present study, all the by-products discussed above shall be taken to produce low cost high fiber value added extruded product.
OBJECTIVES

The present study was therefore, undertaken to develop high dietary fibre content extruded product using carrot pomace, rice flour and pulse powder with overall objective of value addition to by-products. The objectives were -

- To study the drying kinetics of carrot pomace
- Development of high dietary fibre content carrot pomace, rice flour and pulse powder based extruded product
- Characterization of extrudates (Bulk density, hardness, expansion ratio, water absorption index and water solubility index)
- Sensory evaluation of the product
- Optimization of extrusion process parameters
- To study the physico-chemical properties (moisture content, colour, protein and β carotene) of developed extruded product
- Storage stability of the developed product.