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Review Paper

Whey: Composition, Role in Human Health and its Utilization in Preparation of Value Added Products

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Abstract

Whey is defined as milk serum, the liquid portion of milk left after the formation of curd. It is a by-product of cheese or casein and has many commercial uses. Whey has been considered as an excellent source of protein and offers an admirable amount of vitamins, minerals and lactose. Whey may be sweet or acid depending upon the type of casein or cheese coagulated. Over the few years, whey has captured the interest of market where it is sold as a complete protein pack flooded with nutritional imponents in today's populated world. Ample of beverages, both alcoholic (whey beer, whey wines) and non-alcoholic can be manufactured from whey. Whey drinks are highly nutritious and meet certain therapeutic purposes especially serve the purpose of those who are suffering with limited movement of limbs etc. The widespread research depicts the potential health benefits of whey protein concentrate.

Keywords: Whey beverages, whey protein concentrate (WPC), whey protein isolate (WPI), whey protein hydrolysate (WPH).

Why is the left over material from cheese production after the milk fat and casein get separated from whole milk.

Over the years, cheese manufacturers are becoming very much vigilant to utilize whey. It was previously considered as the waste product and usually thrown into sewage which ultimately meant a loss of certain valuable nutrients. The conversions of this whey into various products is considered as the appropriate solution because of nutritional contribution of whey. Since whey contains enough quantities of lactose hence, it could be utilized as a substrate for fermentation. Even lactic acid bacteria can be used for the production of lactic acid. Jolles (1913) prepared a "salutary" drink from whey where in the whey was decolorized and deodorized by charcoal, the addition of acid and the finished drink was produced by the addition of salts, medicaments and carbon dioxide.

Due to its nutritional quality, it is extensively used for praparation of various health drinks. The beverages which are designed to contain whey–protein have become the point of attraction to the markets or manufacturers as it is known to have a complete protein pack. Apart from proteins, whey is a good source of various vitamins, minerals and lactose. The suitability of whey based products for normal nutrition and application in diet therapy comes from its chemical composition, nutritive value and sensory quality. Whey beverages are found in two forms at neutral pH and at low pH. However, astringency is pronounced at low pH. In this article, composition of whey, proteins from whey and beverage production from it has been described.

Whey: Composition and health benefits

composition

Lactose found in whey, is known to have many benefits like stimulation of peristaltic activities in digestive tract, alleviation of calcium and phosphorous absorption, inhibits the growth and spreading of pathogens by providing the slight acidic reaction in the gut. Lactose also ensures the amount of magnesium and enhances the milk fat digestion and other nutrients in humans. Moreover, it doesn't take part in the formation of plaques. There is transformation of the certain amount of lactose into lactulose during heat treatments which is known as bifidobacterial growth promoter (Tratnik 2003). He also suggested that the main constituent of the dry matter of whey is lactose which is an essential source of energy. Vojnovic *et. al.,* (2006) briefly summarized that whey provides basic components like vitamins, minerals, lactose for traditional and evolution of food.

Whey protein is a mixture of globular proteins and includes ß-lacto globulin, α-lactalbumin, bovine serum albumin and immunoglobulin and thermostable fraction of protease peptones. There are three major forms of whey protein named as whey protein concentrate (WPC), whey protein isolate (WPI) and whey protein hydrolysate (WPH). Concentrate is with low fat and cholesterol but consists of higher level bioactive compounds and carbohydrates (lactose). Isolates are basically processed where fat and lactose are removed but still contains the low level of bioactive compounds. While hydrolysates are pre-digested and partially hydrolyzed proteins of whey.

Health benefits

It has been shown that muscle protein synthesis can be improved by the supplementation of the whey protein after exercise (Yang *et. al.,* 2012).Whey protein is used as the source of the amino acids hence, the ongoing research is to find its effect on reducing the risk of diseases like heart attack, cancer and diabetes (Krissansen, 2007). The branched-chain amino acids are abundant in whey protein (Rieu *et. al.,* 2007) which as a fuel for muscles and trigger the protein synthesis (Kimball *et. al.,* 2006). Leucine is the key compound for initiating the transcription process of protein synthesis (Fujita *et. al.,* 2007). When leucine is taken with whey protein then, there would be increased stimulation of protein synthesis, which ultimately speeds up the recovery and adaptation to stress (Ha and Zemel, 2003). However, high heat treatment in combination with pasteurization can lead to denaturation of whey proteins; this denatured whey protein was found to trigger hydrophobic interactions with other proteins that ultimately leads to the formation of gel of proteins, while aggregation upon renneting or acidification of milk is not found with the native whey protein (Foegeding *et. al.,* 2002). It was found in some consumers that the whey protein denatured by heat could cause some allergic problems also (Lee 1992).

Regular consumption of whey can help to meet the daily protein need and might provide some additional health benefits. Jindal *et. al.,* (2004) stated that whey is produced as by-product from casein, cheese, paneer, *Channa*, *shrikhand* and is considered as the product of nutritional importance (Jindal *et. al.,* 2004), while Prendergast (1985) and Mathur *et. al.,* (1988) suggested that whey comprises of certain important nutritious elements such as whey protein, minerals, vitamins and lactose, that are very much important for human dietary requirement **(**Prendergast 1985, Mathur *et. al.,* 1988). Prendergast (1985) demonstrated that whey consumption serves the purpose to supplement those organic and inorganic nutrients to the extra cellular fluid which are lost. Whey has been found to be very beneficial for those people who are associated with hard work like sportsman, athletes, exercising and other people who are involved with same type of work **(**Prendergast 1985; Singh *et. al.,* 2009).

It was suggested by the authors that higher amounts of whey protein can lead to increase cellular glutathione levels (Zavorsky *et. al.,* 2007). Glutathione is one of the antioxidants which is known to defend our body against free radical damage and some toxins. It was suggested study through animals that milk protein can reduce the risk of cancer (Parodi, 2007).

Whey protein concentrate

It has been shown that whey proteins have several functional characteristics such as high solubility and dispersibility. The whey proteins have the capacity of water binding, foaming whipping, emulsification, and gelation and buffering power (Davis and Foegeding, 2007). Foegeding *et. al.,* (2011) determined the whey protein ingredient composition and observed that whey protein ingredients may include WPI (whey protein isolates) and WPC (whey protein concentrates) that range in protein from 25 to 90%

protein. It was shown that α – lactalbumin and betalactoglobulin are predominant whey proteins that range up to 70% of the total protein (Table 1). Geiser (2003) reported significant removal of fat and lactose during the processing of whey protein isolate as a result it was concluded by him that individuals who are lactose-intolerant can often safely take these products (Table 2).

Table 1 : Whey Protein Composition

Whey Protein	WPC %	WPI %
á-lactoalbumin	12 to 16	14 to 15
â-lactoglobulin	50 to 60	44 to 69
Glycomacropeptide (GMP)	15 to 21	2 to 20
Serum albumin	3 to 5	1 to 3
Immunoglobulins	5 to 8	2 to 3
Lactoferrin	<1	Not reported

Source: Foegeding *et al*. (2011)

Table 2: Composition (%) of whey protein forms

Whey components	Whey Powder	Whey Protein Concentrate	Whey Protein Isolate
Protein	11% to 14.5 %	25 % to 89 %	90 %
Lactose	63 % to 75 %	10 % to 55 %	0.5 %
Milk fat	1 % to 1.5 %	2 % to 10 %	0.5%

Source: Geiser (2003)

Evans *et al.* (2010) compared the properties of whey protein and milk serum protein concentrates. Proteins that are separated directly from milk and present in milk is the milk serum protein and when 80% SPC (Serum Protein Concentrates) was compared with commercial WPC (Whey Protein Concentrates). There was lower fat content both higher pH in SPC, but were similar in flavor profiles. Lipid oxidation product was found higher in commercial 80% WPC samples compared with SPC and WPC. The results showed that additional commercial processing parameters enhance the flavor in WPC. Differences were found in sensory profiles of acidified peach- flavored protein (pilot plant and commercial plant) but were no recognized in rehydrated neutral pH protein solution (Evans *et. al.,* 2010). Hammond (1992) suggested that bran which is usually known to be a good dietry fibres. It has to be selected carefully for addition as many fibers' are less soluble or insoluble at all. Stabilized rice bran is one of the best as it is balanced with proper soluble and insoluble dietary fibers' and it was seen that there was no formation of sediments while storing the rice bran fortified beverage and no allergy causing proteins were found. When honey was added in place of sugar then it resulted in fortifying the beverage with other nutrients and phytochemicals which is not naturally contained in the whey (Hammond 1992). Marshall (2004) have also shown protein concentration and fat, lactose and mineral content in different commercially available whey protein source. (Table 3).

Table 3. Types of commercially available Whey Proteins

Product description	Protein Concentration	Fat, Lactose, Minerals Content
Whey Protein Isolate	➢ 90-95%	➢ Negligible
Whey Protein Concentrate	➢ May range from 25-89% ➢ Most commonly available as 80 %	➢ Some fat/ lactose/ minerals which decreases as protein concen-tration
Hydrolyzed Whey Protein	➢ Variable ➢ Hydrolysis used to cleave peptide bonds, creating smaller peptide fractions ➢ Reduces allergic potential compared with non-hydrolyzed	➢ Varies with protein concen-tration
Undenatured Whey Concentrate	➢ Variable ➢ Usually range from 25-89% ➢ Processed to preserve native protein structures : typically has higher amount of immunoglobins and lactoferrin.	➢ Some fat/ lactose minerals which decreases as protein concentra-tion increases

Source: Marshall (2004)

Cheddar whey protein (WPI) mozzarella 80% and whey protein concentrate (WPC80) were manufactured and

stored at 30ºC. After 0, 6, 12, 24, 48 hrs the product was spray dried and the remaining retentate were held until the next time of point. Results showed that lipid oxidation products and sulphur degradation products increased in spray dried products with increased liquid retentate storage times, whereas diacetyl decreased. Shelf-stability was decreased in spray products from layer retentate storage times (Whitson *et. al.,* 2011). The liquid cheddar whey for flavor and flavor variability liquid cheddar cheese whey was collected which was prepared from five culture blends from two different stirred curd cheddar cheese. Instruments and sensory methods were used to assess the whey flavor and wide differences between different manufacturing facilities were found. Differences in liquid whey flavor were attributed to differences in milk source, processing, handling and starter culture (Carunchia *et al.,* 2003).

Fermented Whey beverage

Gallardo *et.al.,* (2005) compared rennet milk and skim milk for the effect of culture, medium, and their interaction on the flavor. It was compared by sensory descriptive analysis and head-space volatile analysis by proton – transfer – reaction mass spectrometry. Samples (WFM, whey from fermented milk; FRM, fermented rennet milk) with different starter cultures like yoghurt, probitic and cheese were assessed. It was found that culture had more effect than media on odor and flavor of the samples. The FRM odour was more intense than WFM when probiotic and yoghurt were used as culture. This characteristic was considerably increased for FRW in case of cheese culture. Whereas the probiotic and cheese cultures gave a slightly less or similarly intense "acid" flavor respectively in WFM than in FRW, yoghurt culture gave a lesser acid product in FRW. It was seen that the whey as a medium for producing the beverage with sensory profile was found to be similar to the fermented milk beverage. Volatile flavor compounds like acetaldehyde and diacetyl were not found to be affected by fermentation medium and exceeded threshold recognition level in all. Unpleasant vinegar odor was however produced with beverage containing probiotic bacteria due to the release of the acetic acid (Gallardo *et. al.,* 2005). Beta – lacto globulin (BLG) is major whey protein and is the main cause of milk allergy. When selected lactic acid and WPC35(WPC containing 35% of proteins) were used to formulate a fermented whey beverage by which the fermented product was obtained with low lactose and BLG contents and high essential amino acids (Micaela *et. al.,* 2010).

Karina *et. al.,* (2010) found that the cheese whey (CW) and deproteinised cheese whey (DCW) can be taken as novel substrates because of their suitability for the production of kefir-like-beverages. It was shown that kefir grains were easily capable of utilizing the lactose easily which was present in the CW and DCW and noticed that there was the similar amount of lactic acid, ethanol and acetic acid produced as in milk fermentation. Hence, CW and DCW could serve as the substrates for the manufacture of the kefir like beverage similar to milk beverage (Karina *et. al.,* 2011). Steady structure and dominant microbiota including the probiotic bacteria in the kefir grains and beverages were found (Karina *et. al.,* 2010). Effect of pH on the ability of the whey protein isolate (WPI) and fish gelatin (FG), alone and in combination, to form and stabilize fish oil-in-water emulsions was also studied. Combined WPI-FG emulsions were prepared and found to have superior physio-chemical stability in comparison to the emulsions prepared with from with individual proteins (Ali *et. al.,* 2011). Listiyani *et. al.,* (2012) showed how the bleaching agent and temperature affected the bleaching of liquid cheddar whey and found that bleaching efficacy of hydrogen peroxide was decreased at 4°C in comparison to that at 68º C, whereas that of benzoyl peroxide was not affected by temperature. Thus, fat separation of liquid cheddar whey has no effect on bleaching efficacy or lipid oxidation and that hot bleaching may result in increased lipid oxidation in fluid whey. When bleached with benzoyl peroxide it had lower norbixin content compared to whey bleached with hydrogen peroxide (Listiyani *et al.,* 2012).

Evans *et. al.,* (2009) found that when serum protein concentrate (SPC) and whey protein concentrate (WPC) were prepared under controlled conditions in a similar manner from the same milk using the same ultra filtration equipment. Further few sensory differences were ..... . Furthermore, flavor (sensory and instrumental) properties of both pilot-scale manufactured protein powders were different from commercial powders suggesting the role of other factors e.g. milk supply, processing equipment and sanitation influencing (Evans *et. al.,* 2009).

Whey based beverage

Mirjana *et.al.,* (2002) stated that the dry component of the fruit, pH of the beverage and its sucrose .... were the independent variables. Beverages with whey and fruit contents (orange, pear, peach and apple) were blended in accordance with factorial design by applying the regression analysis method; a mathematical model of each

characteristic was derived. None of characteristic functions had an extreme, so the maxima lay at the boundaries of the independent variable, only the pH change within the narrow range. The peach- whey beverage contains 6% of dry matter and 2% of sucrose with pH value of 3.6 proved to be the best (Mirjana *et. al.,* 2004).

Milk of 4.5% fat and 8.5% SNF was heated to 82ºC
↓
Coagulated milk protein with citric acid (2%)
↓
Heated to 82ºC to precipitate protein
↓
Filtered through muslin cloth
↓
Centrifuged at 5000 rpm for 10 min
↓
Whey

Figure 1: Process flow chart for the preparation of paneer whey. (Adapted from Sakhale *et. al.,* 2012)

Whey
↓
Dissolved the sugar and stabilizer
↓
Filtered
↓
Mixed filtrate and mango pulp and then, blended uniformly
↓
Bottled in pre-sterilized glass bottles with 2.5 cm headspace
↓
In-bottle sterilized
↓
Cooled
↓
Labeled
↓
Stored at 5-7ºC temperature

Figure 2: Process flow chart for the preparation of whey based mangobeverage**.** (Adapted from Sakhale *et. al.,* 2012)

Sakhale *et. al.,* (2012) demonstrated the development of RTS-drink from mango in combination with whey (Figure 1 and 2). Mango juice and whey were used in different combinations like 70:30, 75:25 and 80:20 for the production of a healthy nutritious (RTS) drink and for the purpose of storage, evaluated for certain physio-chemical and sensory attributes. The study revealed that the 70:30 (70% whey and 30% mango) combination of whey and mango scored the highest for almost all sensory quality attributes e.g. color, appearance, taste, overall acceptance. Ascorbic acid content were also found the highest (9.80/100g). The beverage was found unaltered with respect to TSS content along with storage duration (Sakhale *et. al.,* 2012).

Complications in whey beverages

It has been shown that pH controls the whey protein in beverages. Those beverages with the neutral pH were generally found as opaque and available in flavors such as chocolate, orange, cream etc; beverages with pH<3.5 (acidic) were clear and had fruity flavors (Beecher *et. al.,* 2008). There was some concern related to flavor which was due to the high level of astringency in beverages at high protein concentration and at low pH (Sano *et. al.,* 2005). It was suggested that the astringency was due to some specific compounds like alum (Peleg *et. al.,* 1998), polyphenols (Lesschaeve *et. al.,* 2005) and acids (Lawless et al.1996) used in its preparation. Jobstl *et. al.,* (2004) described the complexation and precipitation which was caused by astringent compounds with salivary proline-rich proteins that increased the friction in mouth perceived as astringency (Jobstl *et. al.,* 2004). Beecher *et. al.,* (2008) suggested that astringency occurred due to the interactions between positively charged whey proteins and the negatively charged saliva protein. It was found that as there is a fall in pH between 3.4 and 2.6; the negative charge on saliva also got decreased that ultimately resulted in the decrease of interaction with whey protein (Beecher *et. al.,* 2008) Sano *et. al.,* (2005) mentioned that whey proteins being more positively charged than gelatin (pH 3.5) caused astringency. When whey proteins at pH 3.5 were mixed with saliva (pH 7.5) it resulted a solution with pH 5 that caused astringency because of whey protein precipitation (Sano *et. al.,* 2005). It has been shown that for the perception of astringency the interaction between whey proteins and epithelial cells of human buccal cavity are known to play an important role in whey based beverages. The factors like protein type, protein concentration, pH and the time on which the binding between the beta-lactoglobulin, lactoferrin and human oral epithelial cells depends also influence this phenomen.

It was observed that as the protein concentration gets increased the astringency also gets enhanced. Further, there was no perception of astringency at pH 3.5 by two types of gelatins. A taste sensor also gave specific value for whey

proteins when at pH 3.5. This astringency was caused due by the proteins in mouth which get aggregated and precipitated under acidic conditions.

Tratnik (2003) described the problem of whey beverages due to the presence of high amount of minerals which were basically responsible for undesirable salty-sour flavor of whey and this was found more in acid whey because of the presence of the high amount of the lactic acid. High amount of minerals like calcium-phosphates and calcium lactates are present due to better solubility but gave acid redundancy and presence of clots in finished product. When such products were given heat treatments, the formation of the sediment was observed (Tratnik, 2003). After this Koffi *et. al.,* (2005) claimed that the preparation of fresh whey beverage was considered the most economical hence led to the production of beverage with added fruit concentrates so that the drink can be obtained with acceptable sensory properties especially flavor (Koffi *et. al.,* 2005). It was observed that when acid whey powder was blended with some frozen, concentrated fruit juices, the valuable nutrient drinks were produced (Frank, 1968). Several bitter taste inhibiting agents for whey protein hydrolysate beverages have also been studied (Pattarin *et. al.,* 2012).

Health importance of whey based beverage

Whey beverages have been found to contain valuable amounts of calcium and riboflavin. Since, the whey beverages have nutritionally best protein and whey component which make whey beverages superior for consumption by the consumers who have limited intake of milk. It was found that when drinks were manufactured from the whey which had high content of calcium and flooded with additional whey protein than it was seen that there was lactose hydrolysis which became the centre of attraction and ultimately led to the minimization of the lactose intolerance (Jelen *et. al.,* 1987).

Daniela and Oren (2013) reported the physiological effects of whey protein and effective role of whey in controling over food consumption and metabolism of glucose has been documented. It was found that the whey protein released some amino acids and peptides during its gastrointestinal digestion which in turn led to the secretion of certain gut hormones eg. Cholecystokinin, peptide YY etc. which ultimately led to insulin secretion which are associated with food intake regulation. Hence, it was found to have some clinical applications for obesity and type 2 diabetes .

Katsanas *et. al.,* (2008) concluded that both the whey proteins and essential amino acids are known for the stimulation of the anabolism of muscle protein. Hence, it was found that whey protein intake helps in improving the skeletal muscle protein accrual by the mechanisms which are beyond the essential amino acid contents, therefore, are considered to improve the anabolism of muscle in old individuals. It was observed that the short term postprandial satiety is changed by the low dose of the whey protein enriched water beverage though there was not much effect on food intake when assessed two hrs after consumption (Robin *et. al.,* 2013).

The long time consumption of whey based beverages drinks decreased prevalence of anemia in children and teenagers which is definitely a positive effect of consumption of these beverages.

Conclusion

Whey due to its rich protein content can be utilized in preparation of various protein rich beverages as well as by removing its astringency. It can be concluded that whey based beverages have nutritional importance and emulsifying nature thus, are employed as the functional beverages and sports drink also. Whey represented the highly rich source of proteins and other components with so many properties which when exploited made a beverage commercially, economical and nutritionally valuable beverage with increased energy value. It can also be used to produce acceptable product in the market.

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