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Cheese: Importance and Introduction to Basic Technologies

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Cheese is a highly nutritious fermented milk product with diverse flavour and texture. When compared to whole milk (3-4% protein and fat), it contains 30-40% protein and fat along with other minerals and fat soluble vitamins. Fewer varieties of cheese are available in Nepal compared to the European and American regions. Due to increased awareness of the health benefits of cheese and expansion of cattle farming in Nepal, the demand and supply of cheese is in increasing trend. To overcome the milk holiday in the surplus season, cheese manufacturing could be an attractive venture. By meeting the quality standards set by national and international bodies, there may be huge opportunity for exporting the cheese. However, still many dairy manufacturers are not aware about cheese production technologies and their implications. Hence, this review is aimed at providing more general information on cheese, its ingredients and steps involved in cheese making.

Key words: Cheese, ripening, bacteria, additives, Yak cheese, milk.

Introduction

Cheese is a fermented milk-based solid dairy product, which features a variety of flavours and is produced all over the world. It is produced by coagulating milk (whole or skimmed milk, partial or whole protein of the milk, butter milk or any combination of above materials) with the help of calf rennet or suitable coagulating agents (microbial or vegetable rennet, vinegar and lemon)and partly draining the whey (Hickey, 2017). Lactic acid bacteria is commonly used to produce acid *in situ* during cheese making (McElhatton & El Idrissi, 2016). Cheese can be prepared from whole milk, partially skimmed milk or skimmed milk, all of which can be obtained from Cow, Buffalo, Camel, Goat, Yak, Sheep, Reindeer, Horse, and Donkey milk, in addition to milk powder (Fox &McSweeney, 2017).

Cheese was believed to be evolved from Tigris and Euphrates rivers (current Iraq) 8,000 years ago when people started to domesticate plants and animals as a source of food (Fox, 2011). The earliest cheese was made in Central Asia by Nomadic tribes (Dalby, 2009; Scott, Robinson, & Wilbey, 1998). However, more than 1400 kinds of cheeses are listed in a record of the University of Wisconsin Centre for Dairy Research (CDR, 2014). Nevertheless, there are 18 common types of cheese and they are: Brick, Trappist, Camembert, Neufchatel, Roquefort, Edam, Gouda, Sapsago, Hand, Cheddar, Limburger, Provolone, Cottage, Cream, Parmesan, Romano, Swiss and Whey cheese (McSweeney, Ottogalli, & Fox, 2017). There are different schemes of cheese classification and they are; (i) classification scheme is based on texture (ii) classification scheme based on method of coagulation (iii), classification based on ripening indices. Under aforementioned scheme, there are several classes of cheese and they are:

- Extra hard verities (Grana Padano, Granone Lodigiano, Parmigiano Reggiano, Asiago, Bagozzo, Bra, Formai de Mut; Pecorino Romano, Pecorino Sardo, Pecorino Siciliano, Pecorino Toscano, Pecorino Pepato, Fiore Sardo etc.)
- Cheddar and related varieties (The British Territorial varieties, Cheshire, Derby, Gloucester, and Leicester, are dry-salted cheeses).
- Cheese with propinic acid fermentation (Semi-hard cheeses such as Maasdamer, Leerdamer, and Jarlsberg. Gruyère etc.)
- Gouda and related varieties (Edam, Maribo, Danbo, Colonia, Hollanda, Norvegia, and Svecia).
- Pasta filata cheese (Mozzarella, Mozzarella di Bufala, Mozzarella di vacca, Caciocavallo, Cascaval, Kashkaval, Provolone, Kasseri, and Kasarpeyniri).
- Cheese ripened under brine (Feta, Domiati, and related cheeses such as Brinza, Beli Sir, Telemes, Kareish, BeyazPeinir etc.).
- Blue cheese [fermented by *P. roqueforti*, Bleu d'Auvergne, Cabrales, Gorgonzola, Danablu (Danish Blue), and Stilton]
- Sheeps', Goats' and Buffalo milk cheese.
- Acid curd cheese (Cream, Cottage, Quarg, some Queso Blanco (McSweeney et al., 2017).

The first cheese industry in Nepal dates back to in 1953, when the government- started producing Yak cheese with the support of the FAO in Lamtang and Rasuwa district. A Dairy Development Section was established under the Department of Agriculture (DoA) and also a small-scale milk processing plant was started in Tusal village in Kavre district. In 1955, a Dairy Development Commission was formed (FAO, 2010). A number of small scale cheese makers initiated production of Swiss Emmental and French Cantal type cheeses in Langtang and Ilam (Nepali Times,

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2018). In Nepal, there are 15 small and medium scale cheese industries so far registered in the Department of Food Technology and Quality Control (DFTQC) and other offices under this department (DFTQC, 2020). Until now, exact data on the export of cheese is not available in Nepal. In recent years, The Himalayan Dog Chew Company has started exporting dry cheese (called Chhurpi in Nepali) to the United States, Britain, Canada and Japan which is commonly referred to as "dog chew" (Onlinekhabar, 2019).

Milk and dairy products including cheese provide vital nutrients for our body such as protein, fat and other minerals like calcium and phosphorous (Johnson, 2016). Cheese contains 3-40% protein and 4-48% fat depending upon the types of cheese and method of manufacturing. Furthermore, cheese is a good source of vitamin A, B_{12}, riboflavin and folates. All the essential amino acids excluding cysteine and methionine are present in cheese in an abundant amount (McCarthy, O'Connor, & O'Brien, 2014).

Besides other nutrients present in cheese, fat plays a very crucial role in sensory perception of cheese. Fat acts as a filler particle in three dimensional protein network of cheese (Khanal et al., 2017) by providing lubricity, creaminess and mouth feel in cheese along with other sensory and functional properties. Besides, it also helps to develop the flavour and influences storage stability of food products (Lashkari et al., 2014).

Milk production in Nepal continues to increase but its market demand has been almost stable. This results in return of large volume of unsold milk from the market. Similarly, discarding excess milk has become an issue in flush season i.e when cattle feed (green grass) is easily available (Timsina and Regmi 2009; Sharma 2017). Hence, it is necessary to make the farmers aware about importance of product diversification to cheese, if milk cannot be consumed fresh. Dairy farmers would benefit if they received technical knowledge about cheese making which in turn increases food and nutrition security in the country and economic status of the farmer.

Cheese production

Table 1 shows production and consumption of cheese around the world. From the Table 1, it can be seen that EU is the largest cheese producer and consumer followed by the US and Canada. In Nepal, cheese production is not as high as compared to other countries and it can be seen from the Table 1 that cheese production has increased in the year 2018 as compared rest of the years' data. Few cheese types, namely Yak, Kanchan (cow) and some processed cheese, cheese spread and Mozzarella cheese are produced in the country both by (Dairy Development Corporation), a state owned dairy enterprise" and private dairies. Most of the cheeses available in the country are imported (FAO, 2010).

Table 2 shows total milk production in Nepal and milk sold by DDC in different years. It can be seen from the table that although DDC is still a major dairy in Nepal, due to production of milk from other smaller dairies, the total milk production in Nepal is much higher compared to milk sold by DDC in different years.

Composition of cheese

Chemical and nutritional composition of cheese varies with variety (Table 3). It can be seen from the table that almost all varieties of cheese contain 5-10 times the nutrients compared to milk with the exception of lactose. The lactose content is low in cheese due to conversion of lactose to lactic acid by the metabolism of bacteria during cheese making and fermentation. Hence, cheese can be consumed by the lactose intolerance patient as well (Rashidinejad, 2017). Some varieties contain more calcium; for example: Cheddar cheese, Swiss, Ricotta, Mozzarella, Monterey Jack, Gouda, Guesoblanco and Colby. Furthermore, higher levels of protein is found in Monterey Jack, Gouda, Cheddar, Swiss, Cottage, Port de Salut, Provolone, Mexican blend or Muenster, and Colby. Cheese containing lower amount of sodium are Swiss, Monterey Jack, Parmesan and Ricotta. Also, there are many kinds of low-fat cheeses varying in several chemical components (The Dairy Council, 2014 & ICUSD and NDC, 2011).

Nutritional Importance of Cheese

Cheese is beneficial from both nutritional and health aspects. Dairy products including cheese have been recommended as a part of healthy diet in many European and American regions (Rashidinejad et al., 2017). Cheese contains all essential amino acids. About 30 and 40% of the daily protein requirement of adult is fulfilled by consuming 100 g of soft cheese and hard cheese, respectively (Scott et al., 1998). The biological value of cheese protein is high. Caseins are the major proteins present in the cheese. Protein content in cheese is inversely proportional to the fat content (Rashidinejad et al., 2017). The ripened cheese can be given to lactose-intolerant consumers as lactose is converted into lactic acid during cheese ageing (Barden, 2010).

Fat content of cheese ranges from 4.3% (regular Cottage) to 35 % (regular Cheddar) (The Dairy Council, 2014). Cheese made from whole milk contains all essential fatty acids and high amounts of unsaturated fatty acids and most of fatty acids are in the form of triglycerides (López-Expósito et al., 2017). The average saturated fatty acids levels in cheese fat is 600 g/kg fat, while average level of polyunsaturated fatty acids and monounsaturated fatty acids is 46 and 235 g/kg fat, respectively. Furthermore, cheese fat also comprises oleic acid (unsaturated fatty acid) and trans-fatty acids. However, there can be variation in oleic acid content due to seasons (Rashidinejad et al., 2017). Conjugated linoleic acid present in cheese fat helps to protect from diseases such as cancer and coronary heart disease (López-Expósito et al., 2017).

Cheese also contains high amount of minerals like calcium, phosphorus and magnesium (Palatnik et al., 2017). Hard cheese contains approximately 800 mg of calcium per 100 g of cheese (Rashidinejad et al., 2017). Calcium in cheese is present in a highly bioavailable form (O'Brien & O'Connor, 2004) and inhibits production of insoluble calcium salts in the intestine by casein phosphopeptides (López-Expósito et al., 2017). Calcium is very important for healthy bones and teeth and cheese is a good vehicle of bio-available calcium (The Dairy Council, 2014). Calcium rich foods enhances decrease in weight in type 2 diabetic patients (López-Expósito et al., 2017). Calcium and phosphorous prevents the risk of osteoporosis, osteomalacia and hypertension as well (Akuzawa, Miura, & Kawakami, 2009). Moreover, cheese is also rich in several vitamins like folic acid, vitamin B_6, and vitamin B_{12} (O'Brien & O'Connor, 2004) and these vitamins reduce risk of atherosclerosis. In addition, cheese is also rich in fat soluble vitamins (A, D, E and K) which are necessary for healthy eyes and skin (The Dairy Council, 2014). Cheese possess very high level of vitamin K which protects against vascular calcification (Akuzawa et al., 2009).

Table 1
Production and consumption of cheese around the world in 2005-2020.

Rank	Country	2005		2006		2007		2011 (1000 MT)		2020	
		Prod	Cons#	Prod	Cons#	Prod	Cons#	Prod	Cons##	Prod	Cons
1	EU										
	1,000 MT	6,480	6,083	6,580	6,152	6,700	6,250	8634	17.1	7779	-
2	US										
	1,000 MT	4,150	4,869	4,325	5,025	4,412	5,110	4807	15.1	6000	-
3	Russia										
	1,000 MT	375	615	405	625	420	660	425	5.8	480	-
4	Canada										
	1,000 MT	352	365	50	336	350	367	330	12.3	430	-
5	Brazil										
	1,000 MT	480	472	495	490	505	501	675	3.6	900	-
6	Argentina										
	1,000 MT	460	405	475	420	488	440	521	11.5	700	-
7	Japan										
	1,000 MT	39	251	39	246	42	247	45	1.9	-	-
8	Mexico										
	1,000 MT	143	230	145	229	147	233	275	3.1	290	-
9	Australia										
	1,000 MT	375	223	362	220	360	215	349	11.7	-	-
10	Ukraine										
	1,000 MT	274	164	210	170	200	150	255	4.1	320	-
11	Korea										
	1,000 MT	24	69	24	69	26	73	4	2	-	-
12	NZ										
	1,000 MT	297	28	285	28	319	28	257	3.5	480	-
13	Taiwan										
	1,000 MT	16	16	18	18	20	20	-	-	-	-
14	Nepal (DDC)* MT	175	-	172	-	174	-	259		-	-
15	Nepal (DDC)** MT	50.3 (2014)	-	48.4 (2015)	-	49.7 (2016)	-	52.7 (2018)	-	-	-

MT= Metric Tonnes, EU = European Union, NZ = New Zealand, Prod = production, Cons = consumption. # is consumption is million pounds and ## is consumption in kg/catput.* is production of cheeses including Yak cheese. ** is production of Yak cheese. [Source: Fox & McSweeney (2017); Singh & Cadwallader (2008); DDC (2020): World Cheese Market (2000-2020].

Table 2
Total milk production in Nepal and milk sold by DDC in different years.

Production details/Year	2014/15	2015/16	2016/17	2017/18	2018/19
Total milk production in Nepal (,1000 MT)	1756	1854	1911	2085	2212
Milk sold by DDC (,1000 MT)	57.00	49.9	48.6	44.4	40.3

Source: DoLS (2020); DDC (2020).

The nutrients present in cheese help to prevent formation of the acid on teeth after eating sugary foods. Other dental problems are reduced by saliva stimulated by consumption of cheese (Akuzawa et al., 2009). Bioactive peptides present in the milk have a hormone like regulatory effect in human body and they may be detached from the parent protein during cheese manufacturing (O'Brien & O'Connor, 2004). They are produced during cheese ripening due to degradation of casein by proteases and peptidases from rennet, milk, starter and non-starter microorganisms. Some of the bioactive peptides are important for the extensive biological functions as they can withstand gastrointestinal digestion. They may act as a precursor for the final peptide production (López-Expósito et al., 2017).

Ingredients for cheese manufacturing

Cheese-making requires a combined knowledge of chemistry, biochemistry, biology and other scientific disciplines. During the cheese making process, enzymes convert milk sugar (lactose) into lactic acid, caseins (a major milk protein) into curd or gel; and other proteins, sugars and fats into flavour, texture and aroma giving components (Fox & McSweeney, 2017). During cheese making, water activity (moisture content) and pH of the milk is reduced, which stabilizes and preserves nutrients present in the milk. Cheese-making is a type of concentration process in which 6 to 12 times more fat and proteins are found as compared to the raw milk (Fox & McSweeney, 2017; Hickey, 2017). Cheese manufacturing processes do not rely merely on the composition of macro-components, such as: fat, protein, ash and lactose, but also depend upon the microstructure of specific components like caseins, fatty acids, albumins and globulins. The caseins to fat ratio is a very important factor to maintain the quality of cheese (Scott et al., 1998). The essential ingredients for cheese-making are: milk, starter cultures, additives, colour, coagulating agents and salt.

1. **Milk**

Quality and type of milk directly affect the quality of cheese. It is obvious that milk from different animals contains different percentages of fat and protein. The amount of caseins and fat in milk determines quality of cheese (Ong et al., 2017). For instance, higher fat recovery takes place in cheese made from goat milk due to the presence of smaller fat globules (McSweeney et al., 1993).

Table 3
Nutritional composition of different types of cheese.

Per 1 oz (28 g)	Whole Milk	Yak cheese	Swiss	Swiss	Yak cheese	Monterey Jack	Ricotta, part-skim	Cheddar	Mozzarella, part-skim	Process American (1 slice/ 21 g)	Blue
Energy (kcal)	18.5		106	106		104	171	114	72	79	100
Moisture		38			38	-	-	-	-	-	-
Protein (g)	0.92	43.6 (DB)	8	8	43.6 (DB)	7	14	7	7	5	6
Fat (g)	1	45 (DB)	8	8	45 (DB)	8	10	9	4.5	7	8
Calcium (mg)	33		224	224		209	337	204	222	116	150
Phosphorous (mg)	26		161	161		124	227	145	131	108	110
Sodium (mg)	12		54	54		150	155	176	175	263	395
Lactose (g)	1.4		0.02	0.02		0.14	0.38	0.07	0.32	0.11	0.14
Salt (%)		1.87 (DB)			1.87 (DB)	-	-	-	-	-	-

Source: [The Dairy Council (2014); & ICUSD and NDC (2011); DDC (2020)].

Goat milk contains lower amount of α_{s1}- caseins than cow milk. However, cow milk is not suitable for some varieties of cheese such as Feta, but is suitable to make Cheddar cheese, a type of hard cheese, in which flavour is developed by the breakdown of α_{s1}- caseins by the rennet enzyme (Hill & Kethireddipalli, 2013).

Prevalence of types of microorganisms and their activity in milk also plays very important role in the natural biochemical reactions in cheese manufacturing. It is well known that lactic acid bacteria are very sensitive to veterinary drugs (antibiotics) which are used for the treatment of various diseases of animals (Panthi et al., 2017). Presence of antibiotics hinders growth of starter bacteria in cheese milk (Fox, 2011). Mastitis is a very common disease in cattle and farmers use antibiotics to treat this condition (Panthi et al., 2017). Commonly used antibiotics are β-lactam group (Penicillin, Ampicillin and Penicillin G), Streptomycin, Tetracycline, Sulphonamides and Amphenicols (Hill & Kethireddipalli, 2013). Presence of residues of these antibiotics interfere with the growth of lactic acid bacteria culture in the cheese (Fox, Cogan, &Guinee, 2017a). Hence, testing for the presence of residues of anti-bacterial compounds in the milk for cheese making is commonly done in many countries (Hill & Kethireddipalli, 2013).

Fat: protein ratio in milk, level of calcium and pH of the milk are important factors to determine cheese quality. These three parameters can be altered according to the need and types of cheese (Fox, 2011).

2. Starter Culture

Starter cultures are micro-organisms (bacteria, yeasts or molds) that are added to the fermented milk products during their manufacture. In cheese, lactic acid bacteria (LAB) (*Lactobacillus and Streptococcous*) are considered as a major acid producer and are referred to as primary cultures. In addition, other bacteria, yeast and mold cultures are also added to cheese for some specific purposes (Cogan et al., 2007). Selection of the cultures depends upon the types of cheese. Cultures are added during cheese making for the following purposes:

- Development of acidity.
- Production of special flavours i.e. acetaldehyde or diacetyl flavour in the cheese.
- Diminishing the late gas blowing defect and food poisoning caused by growth of *Clostridium tyrobutyricum*in cheese.
- To achieve health benefit as probiotics (Hill & Kethireddipalli, 2013).

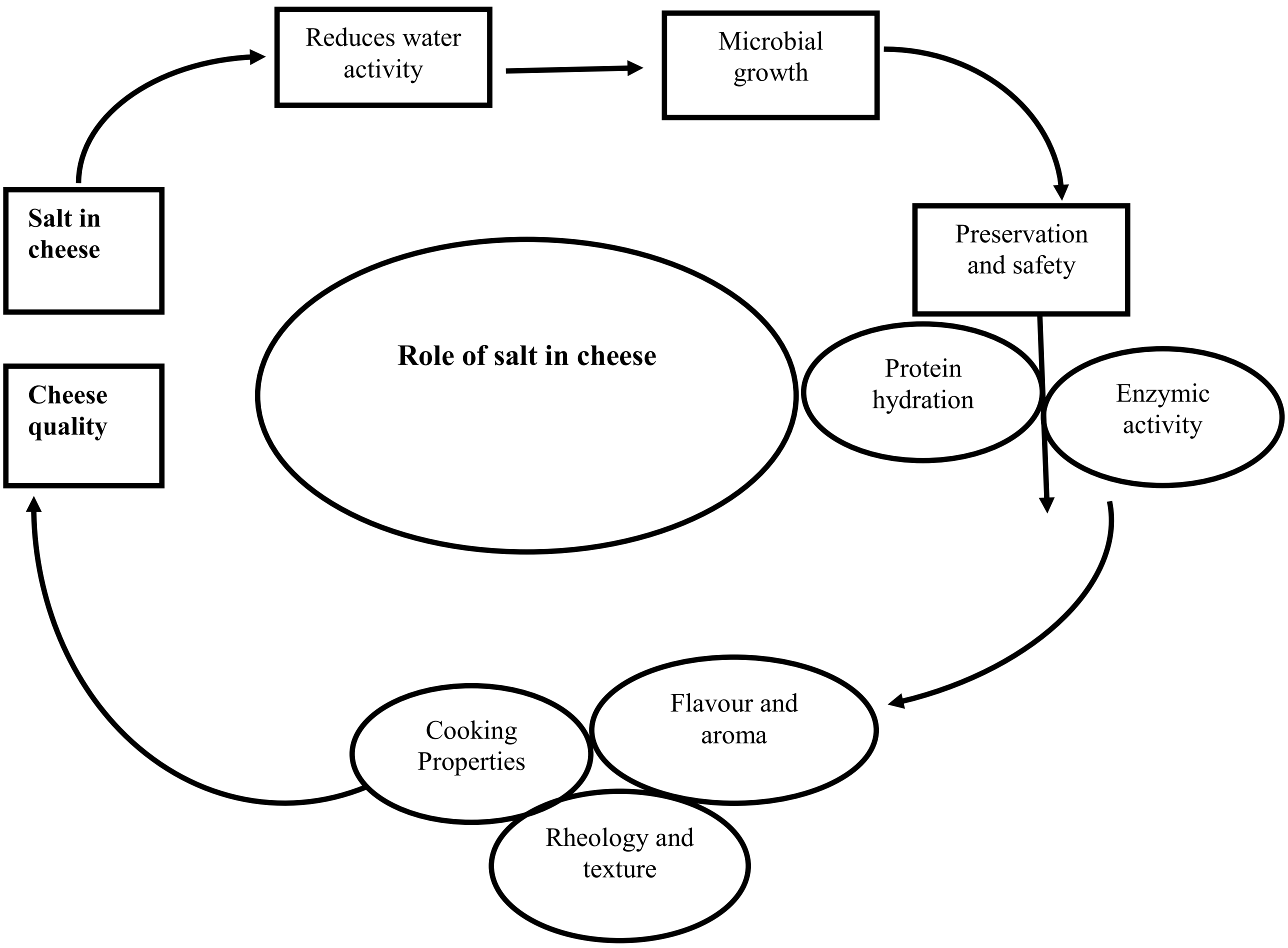

Figure 1. Role of salt in quality of cheese.
(Source: Modified from Guinee, 2004)

Other types of micro-organisms used in specific kinds of cheese are referred to as secondary and adjunct cultures.The major species of starter cultures used to make cheese are *Leuconostoc* sp., *Streptococcousthermophilus, Lactobacillus delbrueckii*, subsp. *lactis, bulgaricus*and *Lactobacillus helviticus*. However, not all of them are used in all types of cheese. *Lactobacillus lactis* and *Streptococcous thermophilus* are used in most cheese types.

3. Salt

Role of salt in cheese manufacturing is very significant due to its preservative action (Figure 1). It also incorporates dietary sodium (to a lesser extent) and controls the growth of both starter and non-starter LAB, pathogenic and contaminant bacteria in cheese (Fox et al., 2017a; Guinee, 2004). Salt imparts flavour to the cheese and checks the growth and metabolism of microorganisms. It also influences the texture of cheese (Kaya, 2002). Sodium chloride (NaCl) or salt is also associated with other functions, such as composition of cheese, solubility of protein, water activity, casein network hydration, calcium and para-caseinate complex interactions and curd syneresis (Guinee, 2004; Johnson,, McMahon, McCoy, & Narasimmon, 2009). The optimum level of NaCl in Cheddar cheese is from 1.8 to 2.1% (w/w) (Rulikowska et al., 2013). Prasad & Alvarez (1999) studied the effect of salt on the physico-chemical characteristics of Feta cheese throughout the ripening and illustrated that harder cheese was developed by a higher percentage of salt in brine. They also demonstrated changes in colour of the cheese by varying salt concentration in the brine.

4. Additives

During cheese manufacturing, chemical agents like calcium chloride, phosphates, sodium or potassium nitrate/nitrite are also used (Herr, 2016). Calcium chloride enhances the rate of clotting and decreases the quantity of rennet required. It also helps to maintain balance between soluble, colloidal and complex calcium ions if vegetables or microbial coagulants are used instead of rennet. For manufacturing some cheese varieties, milk is diluted with water to increase the disaggregation of casein micelles. Sometimes casein becomes more soluble which leads to a higher loss in whey and reduction in cheese yield. Hence, calcium salts are used to overcome the loss of caseins (Scott et al., 1998). Potassium (or sodium) nitrate suppress growth of butyric (*Clostridium tyrobutyricum*) and spore forming bacteria (Genualdi, Jeong, & DeJager, 2018). In addition, it also helps to control the gas-forming butyric acid bacteria (McSweeney, 2007). However, possibility of formation of carcinogenic nitrosamines due to the reaction of nitrate and amino acids limits the use of nitrates in cheese (Fox, Guinee, Cogan, & McSweeney, 2017b). Phosphates in the form of sodium phosphates have been used as stabilizer (Herr, 2016). Nisin, an antimicrobial agent, is also used to control the gas forming bacteria in processed cheese (Düsterhöft, Engels, & Huppertz, 2017). Acidulants (lactic or acetic acid) are used in some cheeses (e.g. Ricotta cheese) and very rarely, phosphoric acid is used in the case where pH of the final product should not exceed 5 (Herr, 2016).

5. Colour

Colour is a crucial factor for consumer preference for any food. There are two types of colour which are very important in the milk (Wadhwani & McMahon, 2012). One is riboflavin, found in serum protein (whey) and another is carotene, found in milk fat of some animals. Most of the riboflavin is lost in whey during cheese manufacturing process and carotene (carotenoid) remains in cheese. There is a massive difference in the colour of milk during summer and winter. Therefore, cheese manufactures in some countries try to maintain the colour for the whole year by adding saffron or annatto (Fox, 2011; Scott et al., 1998). Annatto and beta carotene are used in cheese colourings alone or in combination at 0.06% w/w. Annatto is used for the high fat cheese. Annatto extracts were introduced in food as a colouring before GMP (Good Manufacturing Practice) started (Kang et al., 2010). Carotene colour is effective at a very low concentration only. Cheese made from carotene can become too yellow (Chapman, Thompson, & Slade, 1980).

6. Coagulating agents

Coagulation of milk in cheese is brought about by the addition of the rennet enzyme. This enzyme used in coagulation of cheese can be obtained from three different sources: 1. animal sources; 2. vegetable sources and 3. microbial sources (Ong et al., 2017). Rennet is extracted from the stomach lining of the young calf (Fox et al., 2017a). Crude rennet extract contains the aspartic proteinase enzyme chymosin. Nowadays, rennet is produced using genetically modified microbes by fermentation (Hill & Kethireddipalli, 2013). Vegetable sources of rennet conventionally used in some parts of the world are *Cynaracardunculus, Ficuscarica, Arctium minus* and *Solanumdobium* (Scott et al., 1998).Rennet addition brings two important kinetic actions in the milk coagulation. The primary stage is the proteolysis of micellarκ-casein by the rennet and in the secondary stage, the destabilized casein micelles aggregates and form the gel (Thomann, Schenkel, & Hinrichs, 2008). Though the major role of rennet during cheese making is to coagulate the milk, it also contributes to flavour and texture development of cheese by participating in proteolysis during ageing or ripening (Fox, 1988). Rennet coagulation is directly affected by the type of enzyme used, ratio and composition of the milk ingredients (fat, protein, whey and caseins), presence of calcium ion and pH (Fox et al., 2017a). An optimum pH and temperature for the action of rennet is 6.5 and 30˚C respectively. Firm gel is only produced if there is free calcium (Ca^{2+}) ion available. Hence, ionic calcium (in the form of $CaCl_2$) up to 1mM is added to the cheese milk (Hill & Kethireddipalli, 2013). The curd produced at low pH (4.6-5.0) is inelastic, grainy and coarse due to precipitation of caseins close to their isoelectric point where it remains insoluble. On the other hand, the curd produced at higher pH (5.8-6.6) is more elastic, soft, malleable, shrinkable and it is smoother (Scott et al., 1998).

Cheese manufacturing process

Although the common principle of cheese manufacturing is same for all types of cheese, the manufacturing process differs according to the cheese type. Here, in the flow chart (Figure 2), the manufacturing process of Cheddar, Pasta Filata, American and Feta cheese is given. Cheddar cheese is a kind of ripened and hard cheese which is produced by coagulation of the bovine milk by rennet. Process of Cheddaring is a characteristic step of Cheddar cheese manufacturing (Fox et al., 2000). In Cheddaring, due to pressure developed by piling and re-piling, a very firm texture of cheese is obtained by enhancing cohesion and flow of curd particles (Banks, 2011). The permitted legal standard of Cheddar cheese (USA) for moisture is not more than 39% and fat is less than 48% (Banks, 2004). The general steps involved in cheese making are given in Figure 2.

I. Milk Reception

Analysis of milk is the preliminary step in cheese making after receiving the milk. The milk is analysed to find out the composition and microbial status. This is because the rate of lactic acid production may be slowed down if inhibiting factors for the growth of lactic acid bacteria, such as antibiotics and lacto peroxidase system are present in the milk (Fox, 2011). Microorganisms such as coliforms and thermoduric bacteria also inhibit the growth of lactic acid culture (Panthi et al., 2017). The raw milk received should be of clean, fresh and sound quality to obtain the preferred quality cheese (Scott et al., 1998).

II. Milk Preparation

Different steps for treatment of milk for cheese manufacturing are as follows:

Milk is filtered or centrifuged to remove dirt or suspended particles. Sometimes bactofugation is carried out to reduce the number of spores of *Clostridium tyrobutyricum* (Banks, 2011; Legg et al. 2017).

Pasteurization of milk is performed to kill all pathogenic and harmful microorganisms and to inactivate phosphatase and xanthine oxidase enzymes present in the milk. Pasteurization also increases the yield of cheese by insolubilizing part of the serum protein (Banks, 2011). High temperature and short time treatment at 72°C for 15 seconds is commonly used for continuous pasteurization (Ong et al., 2017).

If milk is high in fat content, cream is separated and again the milk is standardized by adding the required amount of cream to the skim milk (Fox, 2011). Additives including colour and salts (calcium chloride and sodium nitrate) are added before ripening the milk. Additives must be mixed in the milk homogenously and are generally prepared in solution or sometimes in the form of dry salt (Scott et al., 1998). After treatment of the milk, it is warmed up to 30°C and starter culture (1% v/v) is added and left for 45 min to 1.5 h for ripening. Ripening time may vary according to the temperature, types of cheese and quantity of the starter used. Sometimes, the amount of starter is increased to reduce the ripening time (Fox, 2011; Fox et al., 2000).

III. Inoculation

Starter culture is added at a rate of 0.05 to 4% according to the type of starter and preference of the cheese maker. The ripening period becomes shorter if the quantity of the starter culture is greater and vice versa. Freeze-dried direct vat set (FD-DVS) culture is used for large-scale manufacturing process (Banks, 2011).

IV. Coagulation

Most cheese makers choose optimum pH for the addition of rennet to coagulate the milk as pH governs the nature and speed at which the coagulum is formed (Ong et al., 2017). The range of pH used for renneting to prepare most cheeses is 6.5 to 6.35. The ratio of fat to protein and the quantity of whey proteins in the curd also affect the curd firmness. The coagulation process must be brief, cost-effective, and well-regulated and should not cause excessive loss of curd and fat in whey. Usually, rennet is diluted 10 times with water before addition (Scott et al., 1998). Generally, one part of rennet can clot 10,000 parts (0.01%v/v) of milk (Legg et al., 2017) but it depends on concentration and manufacturer instructions.

V. Cutting

Cutting time of coagulum varies between 25 min and 2 h according to the process and recipe. Cheese manufacturers sometimes compute the cutting time by multiplying the time taken to flocculate by three (Scott et al., 1998). Cooking temperature, size of curds, speed of agitation and pH affects the quality of cheese and all these factors vary according to cheese type (Fox et al., 2017a). Cutting time is very important during cheese making as it directly influences the yield and composition of cheese (Lawrence et al., 2004; Ong et al., 2017).

VI. Cooking, whey drainage, cheddaring, salting and pressing

Gentle stirring of the curd during cooking is followed after cutting to prevent excessive crushing and fat loss. The stirring rate is increased when the outer covering of the curd looks like a membrane. Cooking facilitates more discharge of whey from the curd due to contraction and pressure exerted on the curd grains (Fagan et al., 2017). Metabolism of the starter bacteria (present in the curd) is also triggered by increasing the cooking temperature which ultimately increases the production of lactic acid and drops pH (Ong et al., 2017). During cheese making, the level of lactose decreases as it get converted to lactic acid by lactic acid bacteria and even a small decrease has a huge effect on the growth of lactic acid bacteria to produce lactic acid. Therefore, cheese producers follow different techniques to adjust the lactose level in the curd (Düsterhöft et al., 2017). The first method is to lower the pH (by producing lactic acid) and to shrink the curd by heat, the second method is addition of water to the whey so as to increase osmotic pressure across the curd membrane and extract lactose from the curd to whey (Scott et al., 1998). The whey is drained when the pH reaches 6.1-6.5 depending upon cheese variety (Tunick, 2014).

For Cheddar cheese, Cheddaring is essential. However, Cheddaring is not essential for soft cheese. Cheddaring comprises layer by layer packing, turning, piling and re-piling of the curd on each side of the vat so as to matt the curd together and continue discharge of whey from the curd to control final moisture content of the cheese (Ong et al., 2017).

These cheese blocks are then turned every 15 minutes and piled to distribute the temperature uniformly. The traditional method of Cheddaring is piling, turning and re-piling slabs of curd, which in recent years has been replaced by a mechanized conveyor system and Cheddaring towers in large- scale industries. Indeed, the traditional method is still in use for small scale industries (Legg et al.2017).

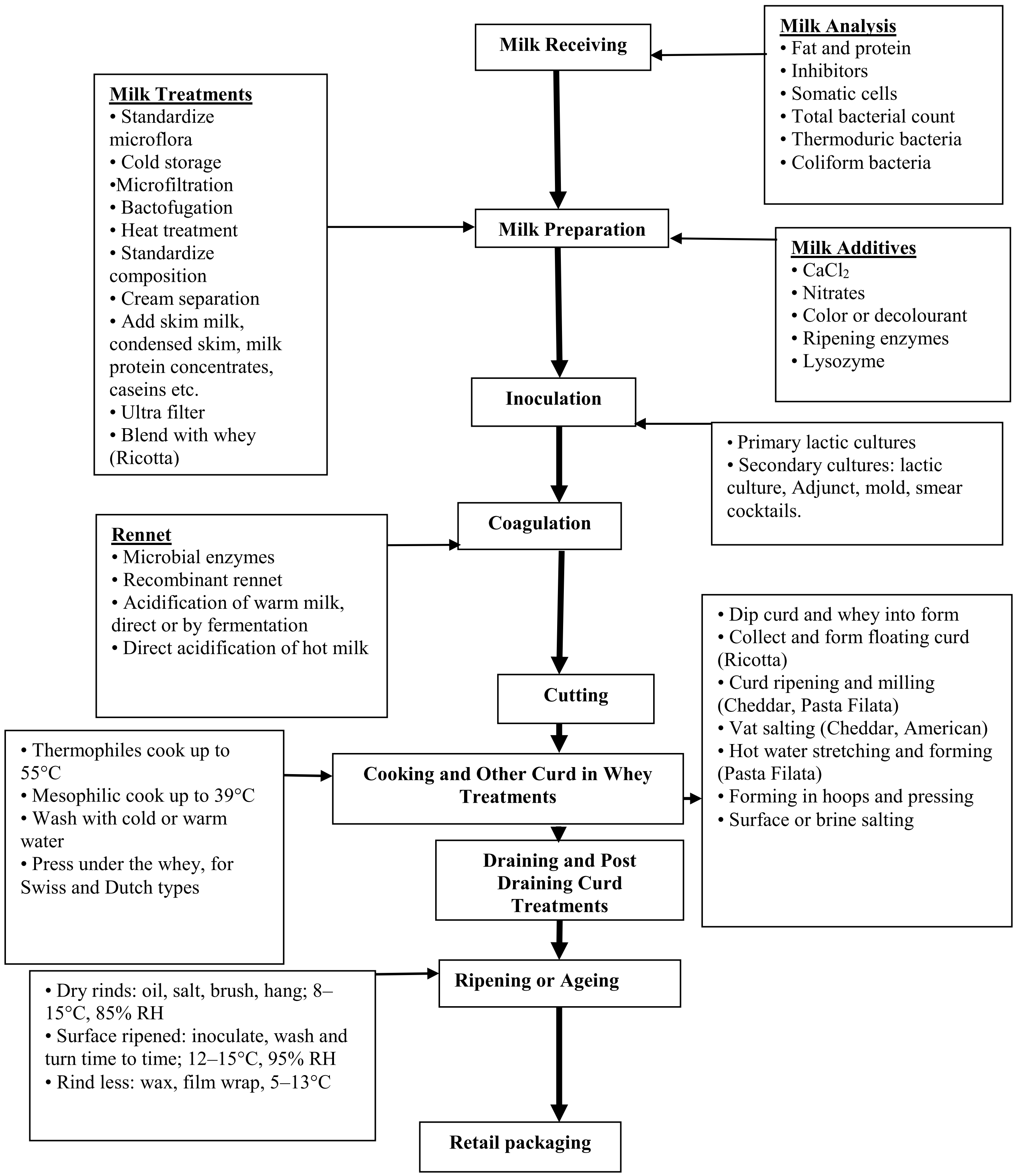

Figure 2. Flow chart of cheese manufacturing process.
(Source: Modified from Hill and Kethirddipalli, 2013).

Indeed, the traditional method is still in use for small scale industries (Legg et al., 2017). The curds are then milled into smaller pieces to facilitate further moisture removal and salting (Lawrence et al., 2004; Zisu, 2005). The size of milled curd is usually 1.5 × 1.5 × 8 cm (Legg et al., 2017).

Concentration of the salt in cheese varies according to the method of application. It also varies according to types of cheese; for example, Cheddar, 1.7%, Emmental, 0.05%, Gouda, 2.0%, Blue, 4.0% and Feta, 7% (Fox et al., 1996). Immersion in brine solution is very common practice for un-textured cheese but dry salting is also commonly done. The salting is a governing factor for further ripening or ageing and proteolysis of the cheese (Ong et al., 2017). Salt should be allowed to dissolve properly otherwise it accumulates around the rind for some time (Scott et al., 1986). The method of salting is also different according to the type of cheese. For blue veined cheese, salting is done on the surface of moulded curd, brine salting is done for Edam, directly immersing the cheese in brine for Gouda Cheese; and dry salting is done for the Cheddar and cottage cheeses. Cheese salted by brine are held to make the curd into a compact mass of appropriate size so as to handle it easily (Guinee & Fox, 2017).

Cheese is pressed after dry salting. Since, pressing also produces a firm and smooth surfaced cheese, pressure applied during initial phase of pressing should be less than the later phase. Applied pressure may be varied according to the size of cheese. Pressure applied in a vacuum is lesser than in normal atmospheric pressure (Scott et al., 1998). Traditionally, for Cheddar cheese, pressure is applied overnight (Ong et al., 2017).

VII. Ripening or Ageing

Ripening is generally attributed to production of desirable texture and aroma in cheese and is governed by the proteolysis and other different biochemical reactions in cheese (Fox, 2011). There are two separate stages during the ripening period. The first stage is from 7 to 14 days, in which reduction in the rubbery texture of cheese is brought about by the residual coagulant enzymes by rapidly hydrolysing α_{s1} caseins to α_{s1}-caseins degradation products (Lawrence et al., 1987). Then the residual ripening period is continued with proteolysis by coagulant enzymes, native milk protease and enzymes produced by starter bacteria and secondary micro-flora (Fox & McSweeney, 2017). Generally, the ripening temperature of Cheddar cheese is 6-8˚C, Emmental is 6˚C for two weeks then 22˚C for 4-6 weeks, Gouda is 12-14˚C and Parmigiano Reggiano is 18-20˚C (Fox et al., 2017a). The ripening time varies from 3 to 12 months (according to the types of cheese) and sometimes longer than 24 months. For the cheese which is not vacuum packed, the temperature and relative humidity ranges from 5 to 12˚C and 87 to 95%, respectively (Hort & Le Grys, 2001).

VIII. Storage and Transportation of cheese

Storage and transportation of cheese also varies according to varieties Hard types of cheese such as Cheddar, Gouda and Nepali Yak cheese can be stored at 8-10°C. The transportation of these types of cheese during winter time (if maximum temperature is 20-21°C), can be transported without chilling for 1-2 hours and if maximum temperature is lower than 15°C then there is no need of chilling facilities during transportation. However, for the softer varieties of cheese such as Ricotta and cream cheese, storage and transportation temperature is nearly 4°C.

Yak cheese manufacturing process in Nepal

Yak cheese manufacturing process begins with the quality control of milk received for its manufacture. Besides the basic platform test of milk, which includes test for fat content, SNF content, acidity as lactic acid, Clot-on-boiling test, alcohol test and organoleptic tests all of which ascertains the quality of milk, hygiene aspects like cleanliness of containers in which the milk is brought and personal hygiene of handler are equally considered as integral aspects.

Milk standardized at 3.5% fat is batch pasteurized in cheese vats and then cooled to an optimum temperature range of 33ºC to 37ºC before inoculating the milk with 1% starter culture comprising of a mix of S*treptococcus thermophillus* and *Lactobacillus helviticus.* This is followed by addition of rennet at the rate of 1.5 to 2.5 gms /100 ltrs milk and then the milk is stirred for few minutes. The milk is incubated for 30 minutes to convert the milk into the curd, then the curd obtained is cut horizontally and vertically using cheese strings followed by draining 30% of the whey obtained. The cheese curd is cooked by raising the temperature of curd to 50˚C within a time span of half an hour. This is followed by stirring the curd using cheese strings. The curd is then further strained with the aid of cheese cloth and then moulded in cheese hoops. This is followed by pressing the curd in hoops using weights equivalent to 1 to 2 times the weight of curd.

The pressed curd block is turned over at regular intervals after which it is left overnight under pressure. The raw cheese blocks obtained are then immersed in brine solution for two days. This is followed by holding the cheese cakes on a rack for a day followed by storage in a ripening room for a fortnight. During this period, the cheese cakes are washed in brine every day and alternately afterwards untill the Yak cheese is completely ripened after about two and half months. After ripening, fat, moisture and salt testing of cheese is done. The cheese is sent to the market after packing in a required retail pack size. Yak cheese is hard and its shelf life is 1.5 to 2 years (DDC, 2020).

Conclusion

Due to a steady growth in dairy farming in Nepal, the dissemination of cheese making technology would be helpful for product diversification of milk to cheese. In addition, it would provide nutrition security through enrichment of high quality protein and uplift farmers' economy besides providing an alternate solution to tackle milk holiday. Government organizations need to take initiative to establish cheese production centres in different parts of the country with special focus on Mozzarella, Yak and Cheese spreads.

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References

Akuzawa, R., Miura, T., & Kawakami, H. (2009). Bioactive components in caseins, caseinates and cheeses. In Y. W. Park (Ed.), *Bioactive components in milk and dairy products* Oxford: Oxford : Wiley-Blackwell

Banks, J. M. (2004). The technology of low-fat cheese manufacture. *International Journal of Dairy Technology, 57*(4), 199-207.

Banks, J. M. (2011). Cheese | Cheddar-Type Cheeses. In J. W. Fuquay (Ed.), *Encyclopedia of Dairy Sciences (Second Edition)* (pp. 706-711). San Diego: Academic Press.

Barden, L. (2010). *Textural Properties of Cheddar Cheese.*

CDR. (2014). *College of agriculture and life sciences, Uinversity of Wisconsin-Madison*

Chapman, H. R., Thompson, S. Y., & Slade, H. M. (1980). The use of carotenoid preparations for colouring Cheddar cheese. *International Journal of Dairy Technology, 33*(4), 162-164.

Cogan, T. M., Beresford, T. P., Steele, J., Broadbent, J., Shah, N. P., & Ustunol, Z. (2007). Invited review: Advances in starter cultures and cultured foods. *Journal of Dairy Science, 90*(9), 4005-4021.

Dalby, A. (2009). *Cheese a global history / Andrew Dalby*. London: London : Reaktion Books.

DDC (2020). Dairy Development Corporation, Nepal. DDC report.

Department of Food technolgy and Quaity Control (DFTQC) (2020). List of cheese industries registered under DFTQC.

Düsterhöft, E.-M., Engels, W., & Huppertz, T. (2017). Gouda and Related Cheeses *Cheese (Fourth Edition)* (pp. 865-888): Elsevier.

Fagan, C. C., O'Callaghan, D. J., Mateo, M. J., & Dejmek, P. (2017). Chapter 6 - The Syneresis of Rennet-Coagulated Curd *Cheese (Fourth edition)* (pp. 145-177). San Diego: Academic Press.

FAO (2010). Dairy sector study of Nepal. Report by Food and Agriculture Organization of the United Nations UN Complex, Pulchowk, Nepal. June 2010.

Fox, P. (1988). Rennets and their action in cheese manufacture and ripening. *Biotechnology and applied biochemistry (USA)*.

Fox, P. F. (2011). CHEESE | Overview. In J. W. Fuquay (Ed.), *Encyclopedia of Dairy Sciences (Second Edition)* (pp. 533-543). San Diego: Academic Press.

Fox, P. F., Cogan, T. M., & Guinee, T. P. (2017a). Chapter 25 - Factors That Affect the Quality of Cheese. In P. L. H. McSweeney, P. F. Fox, P. D. Cotter, & D. W. Everett (Eds.), *Cheese (Fourth Edition)* (pp. 617-641). San Diego: Academic Press.

Fox, P. F., Guinee, T. P., Cogan, T. M., & McSweeney, P. L. H. (2000). Overview of cheese manufacture. In *Fundamentals of cheese science* (pp. 1-17): Springer Science & Business Media.

Fox, P. F., Guinee, T. P., Cogan, T. M., & McSweeney, P. L. H. (2017b). Overview of cheese manufacture. *Fundamentals of cheese science*: Springer Science & Business Media.

Fox, P. F., & McSweeney, P. L. H. (2017). Chapter 1 - Cheese: An Overview. In P. L. H. McSweeney, P. F. Fox, P. D. Cotter, & D. W. Everett (Eds.), *Cheese (Fourth Edition)* (pp. 5-21). San Diego: Academic Press.

Fox, P. F., O'Connor, T. P., McSweeney, P. L. H., Guinee, T. P., & O'Brien, N. M. (1996). Cheese: Physical, Biochemical, and Nutritional Aspects. *Advances in Food and Nutrition, 39*, 163-328. Guinee, T. P. (2004). Salting and the role of salt in cheese. *International Journal of Dairy Technology, 57*(2 3), 99-109.

Guinee, T. P. (2004). Salting and the role of salt in cheese. *International Journal of Dairy Technology, 57*(2 3), 99-109.

Guinee, T. P., & Fox, P. F. (2017). Chapter 13 - Salt in Cheese: Physical, Chemical and Biological Aspects *Cheese (Fourth edition)* (pp. 317-375). San Diego: Academic Press.

Herr, B. (2016). Types and Uses of Additives in Dairy Products☆. In B. Gascoyne (Ed.), *Reference Module in Food Science*: Elsevier.

Hickey, M. (2017). Chapter 30 - Legislation in Relation to Cheese *Cheese (Fourth edition)* (pp. 757-778). San Diego: Academic Press.

Hill, A. R., & Kethireddipalli, P. (2013). Dairy Products *Biochemistry of Foods* (pp. 319-362).

Hort, J., & Le Grys, G. (2001). Developments in the textural and rheological properties of UK Cheddar cheese during ripening. *International Dairy Journal, 11*(4–7), 475-481.

Johnson, M. E. (2016). Cheese: Low fat and Reduced-Fat Cheese *Reference Module in Food Science*: Elsevier.

Innovation Center for US Dairy and National Dairy Council (ICUSD and NDC, 2011). Cheese and nutrition brochure.

Johnson, M. E., K., R., McMahon, D. J., R McCoy, R. D., & Narasimmon, R. G. (2009). Reduction of sodium and fat levels in natural and processed cheeses: scientific and technological aspects. *Comprehensive reviews in food science and food safety, 8*(3), 252-268.

Kang, E. J., Campbell, R. E., Bastian, E., & Drake, M. A. (2010). Invited review: Annatto usage and bleaching in dairy foods. *Journal of Dairy Science, 93*(9), 3891-3901.

Kaya, S. (2002). Effect of salt on hardness and whiteness of Gaziantep cheese during short-term brining. *Journal of Food Engineering, 52*(2), 155-159.

Khanal, B. K. S., Bhandari, B., Prakash, S., & Bansal, N. (2017). Effect of sodium alginate addition on physical properties of rennet milk gels. *Food Biophysics, 12*(2), 141-150.

Lashkari, H., Khosrowshahi Asl, A., Madadlou, A., & Alizadeh, M. (2014). Chemical composition and rheology of low fat Iranian white cheese incorporated with guar gum and gum arabic as fat replacers. *Journal of Food Science and Technology, 51*(10), 2584-2591.

Lawrence, R. C., Creamer, L. K., & Gilles, J. (1987). Texture Development During Cheese Ripening. *Journal of Dairy Science, 70*(8), 1748-1760.

Lawrence, R. C., Gilles, J., Creamer, L. K., Crow, V. L., Heap, H. A., Honore, C. G., Johnston, K. A., & Samal, P. K. (2004). Cheddar cheese and related dry-salted cheese varieties. In P. F. Fox, P. L. McSweeney, T. M. Cogan, & T. P. Guinee (Eds.), *Cheese: chemistry, physics, and microbiology* (Vol. 2, pp. 72-102). Amsterdam; London: Elsevier.

Legg, A. K., Carr, A. J., Bennett, R. J., & Johnston, K. A. (2017). Chapter 26 - General Aspects of Cheese Technology. In P. L. H. McSweeney, P. F. Fox, P. D. Cotter, & D. W. Everett (Eds.), *Cheese (Fourth Edition)* (pp. 643-675). San Diego: Academic Press.

López-Expósito, I., Miralles, B., Amigo, L., & Hernández-Ledesma, B. (2017). Chapter 11 - Health Effects of Cheese Components with a Focus on Bioactive Peptides. In J. Frias, C. Martinez-Villaluenga, & E. Peñas (Eds.), *Fermented Foods in Health and Disease Prevention* (pp. 239-273). Boston: Academic Press.

McCarthy, A. L., O'Connor, T. P., & O'Brien, N. M. (2014). Cheese in the context of diet and nutrition. In V. R. Preddy, R. R. Watson, & V. B. Patel (Eds.), *Handbook of Cheese in Health: Production, Nutrition and Medical Sciences* (Vol. 1, pp. 15-26). Netherlands: Wageningen Academic publishers.

McElhatton, A., & El Idrissi, M. M. (2016). Traditional Polish curd cheesews. In P. SpringerLink Content (Ed.), *Modernization of Traditional Food Processes and Products* (1st ed. 2016.. ed., pp. 4-12): Springer US : Imprint: Springer; Boston, MA

McSweeney, P. L. H. (2007). Cheddar cheese *Cheese: problem solved* (pp. 214-228). Cambridge, England: Woodhead Publishing Limited.

McSweeney, P. L. H., Fox, P. F., Lucey, J. A., Jordan, K. N., & Cogan, T. M. (1993). Contribution of the indigenous microflora to the maturation of cheddar cheese. *International Dairy Journal, 3*(7), 613-634.

McSweeney, P. L. H., Ottogalli, G., & Fox, P. F. (2017). Chapter 31 - Diversity and Classification of Cheese Varieties: An Overview *Cheese (Fourth edition)* (pp. 781-808). San Diego: Academic Press.

Nepali Times (2018): Retrived on 17th May 2020: nepalitimes.com/news.php?id=15426#.XsDWXGgzY2w.

O'Brien, N. M., & O'Connor, T. P. (2004). Nutritional Aspects of Cheese. In P. F. Fox, P. L. H. McSweeney, T. M. Cogan, & T. P. Guinee (Eds.), *Cheese: Chemistry, Physics and Microbiology* (Vol. 1, pp. 573-581): Academic Press.

Ong, L., Lawrence, R. C., Gilles, J., Creamer, L. K., Crow, V. L., Heap, H. A., Honoré, C. G., Johnston, K. A., et al. (2017). Chapter 33 - Cheddar Cheese and Related Dry-Salted Cheese Varieties *Cheese (Fourth edition)* (pp. 829-863). San Diego: Academic Press.

Onlinekhabar (2019). https://english.onlinekhabar.com/a-favourite-nepali-hard-cheese-finds-favour-with-canines.html#:~:text=The%20hard%20cheese%2C%20known%20locally,yaks%20and%20local%20hill%20cows).&text=According%20to%20local%20businessmen%2C%20about,in%20the%20Ilam%20district%20itself.

Palatnik, D. R., Aldrete Herrera, P., Rinaldoni, A. N., Ortiz Basurto, R. I., & Campderrós, M. E. (2017). Development of reduced-fat cheeses with the addition of Agave fructans. *International Journal of Dairy Technology, 70*(2), 212-219.

Panthi, R. R., Jordan, K. N., Kelly, A. L., & Sheehan, J. J. (2017). Chapter 2 - Selection and Treatment of Milk for Cheesemaking *Cheese (Fourth edition)* (pp. 23-50). San Diego: Academic Press.

Parente, E., Cogan, T. M., & Powell, I. B. (2017). Chapter 8 - Starter Cultures: General Aspects. In P. L. H. McSweeney, P. F. Fox, P. D. Cotter, & D. W. Everett (Eds.), *Cheese (Fourth edition)* (pp. 201-226). San Diego: Academic Press.

Prasad, N., & Alvarez, V. B. (1999). Effect of Salt and Chymosin on the Physico-Chemical Properties of Feta Cheese During Ripening. *Journal of Dairy Science, 82*(6), 1061-1067.

Rashidinejad, A., Bremer, P., Birch, J., & Oey, I. (2017). Chapter 14 - Nutrients in Cheese and Their Effect on Health and Disease. In R. R. Watson, R. J. Collier, & V. R. Preedy (Eds.), *Nutrients in Dairy and their Implications on Health and Disease* (pp. 177-192): Academic Press.

Rulikowska, A., Kilcawley, K. N., Doolan, I. A., Alonso-Gomez, M., Nongonierma, A. B., Hannon, J. A., & Wilkinson, M. G. (2013). The impact of reduced sodium chloride content on Cheddar cheese quality. *International Dairy Journal, 28*(2), 45-55.

Scott, R., Robinson, R. K., & Wilbey, R. A. (1998). Introduction to cheese making. In R. Scott (Ed.), *Cheesemaking practice* (Second ed., pp. 37-43). Gaithersburg, Md: Aspen Publication.

Sharma, B. (2017). Milk marketing and dairy value chaina development in Nepal in relation with climate resilience effort in the present context. *Nepalese Veterinary Journal* 34: 144-151.

Singh, T. K., & Cadwallader, K. R. (2008). Cheese. In R. C. Chandan, & A. A. Kilara (Eds.), *Dairy processing and quality assurance* (pp. 273-308). Iowa: Wiley-Blackwell.

The Dairy Council. (2014). *Nutritional Composition of Daiy Products*. The Dairy Council, UK.

Timisina, K. P. & Regmi, P. (2009). Production and marketing dynamycs of milk: A case study of Chitwan district, Nepal. Journal of Inst. Agric. Anim. Science. 30:33-43.

Thomann, S., Schenkel, P., & Hinrichs, J. (2008). The impact of homogenization and microfiltration on rennet-induced gel formation. *Journal of Texture Studies, 39*(4), 326-344.

Tunick, M. (2014). *The science of cheese Michael H. Tunick*. New York: New York : Oxford University Press.

Wadhwani, R., & McMahon, D. J. (2012). Color of low fat cheese influences flavour perception and consumer liking. *Journal of Dairy Science, 95*(5), 2336-2346.

World Cheese Maket (2000-2020). PM Food and Dairy Consulting.

Zisu, B. (2005). *PhD Thesis. Impact of preacidification, fat replacers and exopolysaccharide producing starter cultues on functionality of low fat mozzarella cheese.* (PhD Thesis), Victoria University, Werribee Campus, VIC, Australia.