In terms of innovation and sustainability, many novel approaches have been included in the surfactant industry. This leads to the revolutionary changes in the surfactant market like the sulphate and phosphate free surfactant technologies, alkyl phenol ethoxylate free products and natural origin based surfactant demand.

The development and demand for sugar based biodegradable surfactants have accelerated the recent development of APGs. Since the present research is oriented towards the study of APGs, this chapter is designed to provide a comprehensive review of the synthesis, surface phenomenon and mixed micellization of APGs surfactants.

2.1 Synthesis of alkyl polyglucoside surfactants

Emil Fischer (1893) proposed a fundamentally different approach to the synthesis of alkyl glucosides in 1893 [Fischer (1893), Fischer (1895)]. This process is now well known as the “Fischer glycosidation” and comprises an acid-catalyzed reaction of glycoses with alcohols. In fact, Fischer glycosidation products are complex, mostly equilibrium mixtures of a $\alpha$-anomers and pyranoside/furanoside isomers which also comprise randomly linked glycoside oligomers. Accordingly, individual molecular species are not easy to isolate from Fischer reaction mixtures, which has been a serious problem in the past. Konigs et al. (1901) made some improvement in Fischer reaction and used four step methods for APG synthesis. But this method had some limiting factor for large scale synthesis such as the requirement of heavy metal salts like cadmium carbonate which are used as promoters. Owing to their complexity, the instability of intermediates and the amount and critical nature of process wastes, syntheses of the Koenigs-
Knorr type and other protective group techniques would create significant technical and economic problems. Straathof et al. (1988) and Bocker et al. (1989) reported a simplified transacetalization process to avoid the complication raised due to the usage of stoichiometrically excess fatty alcohol which was suggested by Fischer. Generally, for the same capacity, the transacetalization process results in higher plant cost than the direct synthesis. Borsotti et al. (1996) observed that the type of catalyst may have an influence on the composition of the raw reaction product of APGs.

Rybinski et al. (1998), Hansson et al. (2001) and Basso et al. (2002) reported kinetically controlled, irreversible, stereo specific substitution reactions on suitably activated carbohydrate substrates. These techniques result in the formation of individual species rather than in complex reaction mixtures, especially when combined with protective group techniques.

El-Sukkary et al. (2008) synthesized APGs by the protection of all hydroxyl groups of sugars by acetylation using acetic anhydride/sodium acetate, aldehydes, acetals or benzoyl halides at 140°C in organic solvents or by microwave irradiation under mild reaction conditions (i.e., without solvent or with reduced catalyst loading) followed by de-protection by sodium methoxide in ethanol.

Aken et al.(1986), Crout et al.(1998) , Vulfson et al.(1990), Hansson et al.(2001), Basso et al.(2002) and Gargouri et al.(2004) reported various protective group techniques such as the activation of carbohydrates at the anomeric carbon by leaving groups viz. halogen atoms, sulfonium group, trichloroacetimidate group or by base activation before conversion with triflate esters.
Holmberg (2001) developed a novel approach for stereo-selective formation of beta-O-glucosidic linkages in glycoside synthesis by using environmentally benign heterogeneous catalyst. Development work over this period has enabled the efficiency of synthesis route to be increased to a level where it has finally become attractive for industrial application.

For industrial production of alkyl polyglucosides, processes based on the Fischer synthesis have been successfully adopted. Fischer-type processes are comparatively less complicated and easier to carry out on a commercial scale.

Lin et al. (1979), Rather et al. (2010) developed stereo-selective methods on a laboratory scale to synthesize a variety of model APG substances.

Corma et al. (1998), Roy et al. (2007) revealed the main drawback of the usage of bulk alcohol and strong mineral acids in the Fischer synthesis. Bornaghi et al. (2005) recently have used microwave irradiation to decrease reaction times and to increase the product yield and purity of APGs since product quality and product yield are critically influenced by the time. The loss of alkyl polyglucoside active substance in the reaction mixture correlates well with the formation of polydextrose. The type and concentration of the substances formed by secondary reactions were dependent on process parameters, such as temperature, pressure, reaction time, catalyst, etc.

Roy et al. (2007) suggested that microwave irradiation is not suitable for large scale preparation as most polar alcohols undergo quick degradation under microwave irradiation.

Several researches are still ongoing to find out the efficient method for the synthesis of APGs i.e., minimizing side reactions or waste and emissions. This include the separation of APGs from the raw reaction product, washing the product, recovering and possibly recycling alkyl
polyglucosides and unreacted alcohols together with flexible technologies which allow product properties and quality features to be adapted to market requirements.

**Corma et al. (1998), Roy et al. (2007)** used large amount of catalyst, mostly FeCl₃, SnCl₄, phosphotungstic acid, phosphomolybdic acid (50-100% by weight compared to the amount of sugars) at high temperature (80°C) to promote synthesis of APGs with moderate yield. The chemical route applied for the synthesis of APGs involves extreme of temperature, pressure, use of toxic catalysts, and multiple steps of protection, de-protection and activation. This was overcome by the biocatalyst based synthesis.

**Rather et al. (2010), Rather et al (2012), Rather et al (2013) and Rather et al. (2015)** synthesized APGs by biotransformation of methyl-β-D-glucopyranoside by using cell bound β-glucosidase of Pichia etchellsii whole cell. A maximum of 27 and 13% yield was reported for decyl and dodecyl-β-D-glucopyranoside, respectively. These biological routes avoid the high temperature, pressure and the toxic catalysts used in multiple protection and de-protection steps. Since they operate at near neutral pH, ambient temperature, atmospheric pressure and catalyse enantio- and region- specific reactions. **Holmberg (2001)** reported the enzymatic synthesis of APGs using glycosidase enzyme which had advantages over the chemical route.

**Benesova et al.(2010), Hansson et al.(2001), Basso et al.(2002), Ito et al.(2007), Bae et al.(2011), Kwon et al.(2007), Garcia et al.(2000), Lirdpramongkolaou et al.(2000), Ducret et al.(2002), Papanikolaou (2001), Yi et al.(1998), Turner et al.(2007), Smaali et al.(2007), Makowski et al.(2009), Bilankikova et al.(2010) and Ochs et al.(2011)** reported the trans-glycosylation route, with the yield ranging from 4-97%. It can also be seen that much of the reported work has involved the use of bacterial or the almond enzyme (which is commercially
available). Whole cell catalysis is a relatively newer area but gave the high yields reported with some microbial cells; this approach requires an in-depth study. The glycosynthase technology is now well established and substantial improvements have been made in this area to make enzymatic synthesis a more attractive option.

**Earle et al. (2008)** introduced an elegant new strategy to enhance yield in glycosidase catalyzed reactions by the use of ionic liquids in place of organic solvents to suppress the water activity of the system.

**Gargouri et al. (2004), Hancock et al. (2005), Earle et al. (2008)** have developed a number of strategies like the use of immobilized enzymes biocatalyst to increase the yield in enzyme driven synthesis of APGs.

**Wang et al. (2012)** reported β-Glycosidase driven synthesis using either the reverse hydrolysis or the trans-glycosylation approach. The moderate yields (up to 62%) have been reported for lower chain length AGs, namely, methyl glucoside/xyloside and ethyl glucoside/xyloside, in the reverse hydrolysis approach over prolonged reaction times.

Since APGs are used in wide range of applications particularly in personal care products, membrane protein research, as boosters for antibacterial agents, the chemical route of synthesis is followed currently for large scale production of these compounds.

2.2 **Surface active properties of Alky polyglucosides**

2.2.1 **Measurements and analysis of surface interactions**
Hughes and Lew (1970) reported the fundamental characteristics of APGs. They had investigated the surface tension of alkyl poly-glucosides as a function of alkyl chain and the degree of polymerization.

Shinoda et al. (1961) performed the first systematic study of APGs. Shinoda et al. (1989) showed that the addition of lyotropic salts to aqueous solutions of alkyl mono-glucosides has no significant effect on surface tension. Only a slight shift in the CMC towards lower concentrations was observed.

Nickel et al. (1992) reported that the degree of polymerization has only a minor influence on CMC of APG_{12/14} and above the CMC, APGs exhibit very low interfacial tension against hydrocarbons.

Kutschmann et al. (1995) investigated the interfacial tensions of various APGs against three oils (decane, isopropyl myristate and 2-octyl dodecanol) differing in structure and polarity. The influence of oil polarity was clearly illustrated by comparing the interfacial tension of aqueous solutions of alkyl mono-glucosides against different oils. The CMC values apparently shifted to higher values with increasing oil polarity. The longer alkyl chain having alkyl poly glucoside possessed higher hydrophobicity. Therefore, they are more soluble in oily phases.

Aoudia and Zana (1998) investigated aggregation behavior, CMC, and micelle aggregation number of octyl glucoside, dodecyl maltoside, and 6-O-(N-heptylcarbamoyl) methyl-beta-D-glucopyranoside in water and water-polymer solutions. The micelle aggregation number proved to be nearly invariant with temperature and concentration; the micelles were relatively mono-disperse.
Pastor et al. (1998) studied the hydration behavior of octyl beta-D-glucopyranoside. A hydration number of 16 for monomers below the CMC were calculated. The hydration number was strongly reduced in the micellar state. At low concentrations, a micellar aggregation number of 54 were found which increased to 104 for high concentrations.

Zhang et al. (1999) analysis was based on the combination of X-ray and neutron scattering experiments which indicated that the concentration-dependent micelle growth of beta-D-glucopyranoside was restricted to the change in micelle length. It was proposed that the micelles are cylinders growing in length on higher surfactant concentration. The micelles were assumed to have an irregular and dynamic structure with extensive mixing of core, shell, and solvent.

The electrolyte solutions were used instead of pure water in many industrial applications. On account of this, Holmberg (2003) analyzed the influence of an electrolyte on the interfacial activity of alkyl polyglucosides. Even with extremely large additions of NaCl of more than 20% to the aqueous phase, the plateau value of the interfacial tension against decane remained substantially constant.

El-Sukkary et al. (2008) measured the surface tension by Whilmey plate method. The critical micelle concentration (CMC) values of the pure alkyl polyglucosides and the technical alkyl polyglucosides were comparable with those of typical nonionic surfactants and decreased distinctly with increasing alkyl chain length. The alkyl chain length had a far stronger influence on the CMC by comparison with the number of glucoside groups of the alkyl polyglucoside.

Nilson et al. (1998) used Nuclear magnetic resonance (NMR) self-diffusion measurements and time-resolved fluorescence quenching to get information about the micellization of beta- D-
glucopyranosides. According to their results, non-spherical aggregates were formed with an axial ratio of approximately 11:1.

**Rojas et al. 2005** compared an EO-based hexa-oxyethylene dodecyl ether with n-dodecyl-β-d-maltoside and revealed that the surface charge density decreased with the increase of APGs.

**Wang et al. 2015** reported synthesis of APG₁₂ from n-dodecyl alcohol and glucose in catalysis system of p-toluenesulfonic and phosphoric acid. Using the method of direct glycosidation, this work discussed the impact of raw material ratio, catalyst dosage and reaction temperature on the synthesis. It was concluded that for the synthesis of APG₁₂, best reaction process condition are the molar ratio of alcohol and glucose 7:1; the reaction temperature of 115°C and the amount of catalyst 1.3%, controlling the reaction pressure in 3 - 4 kPa.

**Balzer. (1991), Balzer et al. (2000), Iglauer et al. (2009), Hill et al. (1997), Iglauer et al. (2009), Iglauer et al. (2010), Wu et al. (2010), Balzer. (1993), Kahl et al. (1997)** measured IFT values by tensiometric methods and proved the APG formulations can reach low to ultra-low interfacial tension (IFT) values *i.e.*, 0.01-0.001mN/m against hydrocarbon phases. The IFT values were largely independent to temperature and salinity. These properties were widely used in improved oil recovery. Their studies also revealed that the APGs with long alkyl chain exhibit low solubility both in water and in non-polar solvents. Thus, they displayed higher interfacial property.

### 2.2.2 Emulsion properties

**Forster et al. (1996)** synthesized a micro-emulsion of APGs consisting of dodecyl and tetradecyl alkyl chain. They proved the temperature invariant micro-emulsion properties of APGs by small angle X-ray scattering and conductivity tests.
Piispanen et al. (2004) have reported that the APGs consisting of single sugar unit shows surprisingly good emulsification properties.

Corrigan et al. (2002), Gouymann (2002) conducted an intense research and reported that depending on the type of formulation APGs play a various role in solubilization or stabilization of cosmetic active/drugs in different liquid preparations, *viz.* improve physical stability and textural characteristics of emulsion systems and semisolids, or alter the flow properties of powders and granulates in the manufacturing of solid cosmetics or pharmaceutical dosage forms.

Savic et al. (2005) elucidate the structure properties relationship of binary systems with cetearyl glucoside and cetearyl alcohol to develop an optimal formulation with the acceptable rheological performance and balanced bulk/fixed water ratio. Polarization and ordinary light as well as transmission electron microscopy, small and wide-angle X-ray diffraction, continual and oscillatory rheology and thermal analysis were used for the systems characterization.

Savic et al. (2011) analysed the lyotropic potential of cetearyl glucoside and cetearyl alcohol mixed micro-emulsion by X-ray diffraction, thermal analysis and rheological measurements. All these results suggested that the hydrophilic gel consists of mixed cetearyl glucoside/cetearyl alcohol crystalline bilayers entrapping the water inter-lamellarly by hydrogen bonding. Though a large number of commercial surfactants were available, a proportionally small group of them are approved as pharmaceutical excipients, and APGs were the one among them.

Tasic-Kostov et al. (2012) and Savic et al. (2011) investigated the colloidal structure of APG_{12}-mixed emulsifier system to be considered as a suitable vehicle for drugs/cosmetic actives.
Tosic – Kosotov et al. (2012) investigated the physical stability of an APG based emulsion such as rheology, polarization microscopy and pH with and without the active lactobionic acid and the safety profile and moisturizing potentials were investigated using the skin bioengineering method. The results revealed that the lactobionic acid in APG-based emulsion showed satisfying antioxidant activity with the considerable enhancement in the treatment and prevention of the photoaged skin.

Monch et al. (2000) studied that the micro-emulsion formed by the APG/FAES act as a good skin compatible cosmetic product by the contribution to cleaning performance and foam while the oil acts as a re-fatting care component. The temperature invariant micro-emulsions of APGs exhibit percolation behavior on phase inversion as a function of co-surfactant content.

El-Sukkary et al. (2008) studied the emulsifying power of the prepared alkyl polyglucoside series against light paraffin oil. The results showed that the emulsion stability increases with increase of alkyl chain length by increasing the solubility of the surfactant in the oil phase, forming a highly stable emulsion.

Chai et al. (2005) analyzed the dielectric relaxation spectroscopy of micro-emulsions for nonionic surfactant octyl polyglucoside butanol/cyclohexane/water system. The experiment showed that the permittivity decreases with the increase in the frequency and clear dielectric relaxation phenomena were observed. Permittivity obviously decreases with the change of the micro-structure of the micro-emulsion, W/O, and O/W can be distinguished by the permittivity.

Savic et al. (2005), (2011) and Pantelic et al. (2014) have investigated the use of various APG mixed emulsifiers as potential stabilizers for pharmaceutical emulsions.
Savic et al. (2011) assessed the physical stability of cream samples by polarization microscopy with cetearyl glucoside and cetearyl alcohol with oils of different polarity indices viz. 18.7, 21.3, 24.2, 26.65 and 43.7 mN/m, respectively. The results revealed that the specific anisotropic texture in all cream samples was not changed by the oil polarity.

2.2.3 Wetting, foaming and other physico-chemical properties of APGs

Busch et al. (1993), Schrader et al. (1994), Busch et al. (1993) revealed that APGs foam considerably better than fatty alcohol ethoxylates, the foam volume increased with percentage of short carbon chains in the alkyl polyglucosides. They are comparable with betaines and sulfosuccinates, but do not match the initial foam behavior or foam volume of alkyl ether sulfates. They also reported that APGs form moderate and stable foams.

On the other hand, APGs can stabilize the foam of anionics in hard water and in the presence of sebum so that up to 20% of surfactant can be saved for the same foaming power.

El-Sukkary et al. (2004) investigated the foaming ability of APG8 – APG14. The APG12 have been reported to have higher foaming ability and the stability of foams increased with increase of alkyl chain length. They have reported low foaming power with respect to other cationic surfactants although they were better than other non-ionic surfactants.

Rafati et al. (2012) revealed that alkyl polyglucosides (APGs) are found as good foaming agent that remained about 130 min at maximum (10,000 ppm) surfactant concentration. In this study, alkyl polyglucosides were recognized as a stronger foaming agent that prepared 54 cm initial foam height in comparison with lignosulfonate which only made about 20 cm.
Jurado et al. (2009) studied the wetting ability of APG\textsubscript{12/14} and it was revealed that the APGs have good wetting ability. Moreover, it was increased by the addition of alcohol ethoxylates.

Zhang et al. (2003) studied the wetting and foaming ability of APGs. The results indicated that the wetting ability of oxo-C\textsubscript{10-11}APG and oxoC\textsubscript{12-13}APG were better than the natural alcohol C\textsubscript{8-10}APG and C\textsubscript{12-14}APG and the foaming abilities of oxo-C\textsubscript{10-11}APG and oxoC\textsubscript{12-13}APG were worse than those of natural alcohol C\textsubscript{8-10}APG and C\textsubscript{12-14}APG. It was also found that there are no real differences in surface tension and detergency between APG of natural alcohol and oxo-alcohol.

Pantellic et al. (2014) revealed that APG surfactants are capable of forming foam with balance combination of excellent dermatological properties along with preserved mildness. This property is highly applicable in cosmetic cleansing preparation.

Han et al. (2009) investigated APGs in washing the field weathered crude oil contaminated soils (COCS) with relatively high oil concentration (123 mg\textsuperscript{1} dry soil) from Jilin Oilfield, Northeastern China. APG\textsubscript{12/14}, with longer alkyl chain, was more effective than APG\textsubscript{8/10} in crude oil removal. Moreover, eminent effect on removal of large n-alkanes was achieved from the synergy between APG\textsubscript{12/14} and inorganic salts, which was opposite to the effect when they were added separately. This study demonstrated a promising way to remediate COCS with ecologically compatible APG surfactant and provided guidelines for its practical application.

Keck et al. (2014) performed the contact angle analysis of the aqueous solutions/dispersions of the APGs on cetyl palmitate films. The study revealed good wettability for all APG surfactants. Cetyl palmitate based SLN were prepared by hot high pressure homogenization and subjected to particle size, charge and inner structure analysis. 1% of each APG was sufficient to obtain SLN
with a mean size between 150 nm and 175 nm and a narrow size distribution. The zeta potential in water was $\sim$ -50 mV; the values in the original medium were distinctly lower, but still sufficient high to provide good physical stability. Physical stability at different temperatures (5°C, 25°C and 40°C) was confirmed by a constant particle size over an observation period of 90 days in all dispersions. Also, the use of APGs for the stabilization of lipid nanoparticles was superior in comparison to classical stabilizers. Further, the results indicated that the length of the alkyl chain of the APG influences the diminution efficacy, the final particle size and the crystallinity of the particles. APGs with short alkyl chain led to a faster reduction in size during high pressure homogenization.

**Song et al. (2000)** investigated dispersion properties of precipitated calcium carbonate suspensions adsorbed with alkyl polyglycosides in aqueous medium. Within the investigated pH ranges, the adsorption curves of alkyl polyglycosides on calcium carbonates showed sigmoidal shapes. At positively charged surfaces of low pH, the adsorption amounts were greater than those at negatively charged surfaces, indicating that alkyl polyglucosides were negatively charged in aqueous solutions. At low concentrations of alkyl polyglycosides, the dispersion stabilities of suspensions were very poor.

### 2.3 Biodegradability of alkyl polyglucosides

**Schobert et al. (1994) and Madsen et al. (1996)** tested the ready biodegradability nature of APGs. **Toshima et al. (1995)** analyzed the biodegradability of the APGs with different alkyl chain length viz. APG$_{9-11}$, APG$_{9-13}$ and APG$_{8-18}$ by shake culture test.

**Madsen et al. (1996), Lee et al. (1995)** determined the biodegradability of APGs with carbon chain C$_8$, C$_{10}$, C$_{12}$ & C$_{14}$ by shake culture tests, semi-continuous activated sludge test and
continuous activated sludge. APGs showed 100% foam loss in all tests i.e. both in sewage treatment plant as well as in surface water conditions. In closed bottle test for evaluating the ultimate biodegradability, APGs exceeded the ready biodegradability limit (60%) of OECD with 75% BOD_{28}/COD.

Madsen et al. (1996) examined the biodegradability of branched octyl polyglucosides and linear C_{12-14} based APGs. Anaerobic biodegradability tests showed that the linear APG was degraded both aerobically and under methanogenic conditions (mineralized >70%). In contrast branched octyl polyglucoside resisted the anaerobic degradation.

Scott and Jones (2000) analyzed the environmental compatibility of APGs from the aspect of their biodegradability. However, the analysis of the level of their environmental interference needs to be much wider so as to comprehend both their direct and indirect effect on the environment. APGs were used in a number of ways. The most frequent use of APGs was in cosmetics, household cleaners, detergents and agriculture. It has been subject to analysis in a number of studies using OECD biodegradation tests [Davies et al. (1992), Steber (1995), Madsen et al. (1996), Steber et al. (1997)].

Qin et al. (2006) proved that the biodegradability of the APGs with longest alkyl chain length has shown comparatively lowest level of biodegradation irrespective of the initial concentration.

Grzeskowiak et al. (2008) studied the biodegradation of APG series viz. octyl, decyl, dodecyl monoglucosides, octyl, decyl, dodecyl diglucosides, octyl, decyl, dodecyl, tetradecyl monoglucosides, dodecyl, tetradecyl diglucosides and dodecyl, tetradecyl triglucosides under the conditions of the OECD screening test with activated sludge as inoculums. It was reported that
APGs with a longer alkyl chain were biodegraded faster than those with a shorter one. However, a longer sugar chain caused slower biodegradation of APGs and the central scission pathway of biodegradation was confirmed. It was also found that the biodegradation rate of apes for mono-, di- and triglucosides was different. A higher content of glucose in APG chains leads to slower primary biodegradation. Qin et al. (2006) also suggested these results.

Steber et al. (1995), Jurado et al. (2011), Jurado et al. (2013) applied a number of internationally accepted biodegradation tests. In particular, the OECD ready biodegradability tests (OECD, 1992) were used to establish the ultimate biodegradation of APGs. The biodegradability of APG$_{12}$ by closed bottle test, the modified OECD screening test and the dissolved Organic carbon (DOC) Die away test resulted in a very high degree of ultimate biodegradation over the 28-day test period.

Pantellic et al. (2014) reported that the population of 81 million inhabitants would use 580,000 tons of this APG products per year and would consume an average of 200 L of water per inhabitant per day. As per the calculation carried out the concentration of detergent – range non-ionic surfactants in raw sewage would be 10mg/L for 5-10% content in detergents. Since APG elimination in sewage treatment plants exceeds 99%, it is predicted that the APG effluent concentration will be below 100µg/L i.e. under the OECD limit for ready biodegradability.

2.4 Mixed micellization properties

Balzer (1993) found that the cloud point of APGs increased by the addition of alkali and anionic surfactant, but decreased by salts. As a result of adding cationic surfactants, which form mixed micelles with APGs, the cloud point initially decreased, passed through a minimum and then increased.
Balzer (1993), Douglas et al. (1999), Komaromy et al. (1996) and Nilson et al. (1984) reported that tiny amounts of SDS added to water-APG$_{10}$ mixtures produce such large changes in the phase behavior and causes the miscibility gap to vanish completely due to the electrostatic inter-micellar repulsion caused by the partitioning of the ionic surfactant into the nonionic micelle.

Sierra and Svensson (1999) found a favorable interaction between APGs (C$_{10}$-C$_{12}$) and different surfactants *viz.*, sodium dodecyl sulfate, dodecyltrimethylammonium bromide and dodecylhaepaethylene glycol ether. Their surface tension and CMC studies proved that the alkylglucosides with shorter chain length were found to have stronger interaction.

Ryan et al. (1999) and Ryan et al. (2001) found that the efficiency of water-CkOC$_2$OCk-APG micro-emulsions increased dramatically with the addition of small amounts of ionic surfactant additive as a result of electrostatic stabilization of the micro-emulsion surfactant monolayer. The different multi-phase states of micro-emulsions with alkyl alpha-D-glucopyranosides were destroyed at low temperature due to the precipitation of the surfactant. The addition of alkylsulfates to the ternary mixtures moves the single phase region to higher temperatures. The three-phase region shrinks with increasing anionic surfactant concentration. The monolayer spacing increased because of electrostatic interactions, which explains the higher efficiency of the non-ionic/anionic mixtures.

Zhang et al. (2004) reported the study of mixtures of n-dodecyl-β-D-maltoside with sodium dodecyl sulphate, dodecyltrimethylammonium bromide and pentaethylene glycol monododecyl ether surfactant in aqueous solutions using surface tension and fluorescence techniques. In this
study the magnitude of interactions between APGs and other surfactants followed the order anionic/nonionic>cationic/nonionic >nonionic/nonionic mixtures.

Wang et al. (2005) analysed the binary mixtures of multi-degree polymerized dodecyl polyglucosides with different types of surfactants viz, trioxethylenenated dodecyl sulfonate, dodecyl trimethylammonium chloride, hexaoxyethylenated trisiloxane surfactant and hexaoxyethylenened-2, 6, 8-trimethylnonanol. The molecular exchange energy calculations of these mixtures suggested that the binary mixtures have decreased surface energy of mixing for dodecyl polyglucosides.

Sattam et al. (2006) proved the synergistic behavior of APGs (C_{12/14}) by the foaming capacity of APG with sodium dodecylsulfate, which showed highly stabilized foaming behavior in both distilled water as well as in hard water of hardness level up to 324 ppm. In advance, Patel et al. (2008) performed the in-vitro and in-vivo biological activity evaluation and confirmed that encapsulated peptide was compatible with APG.

Rosen (2004) and Jurado et al. (2008) reported the improvement on the detergency or the improvement of the oil solubilization in the mixed micelles of APGs with ethoxylated alcohols.

Jurado et al. (2009), Jurado et al. (2010) studied the effect of water hardness and citric acid concentration on the wetting power of the mixed micelles of APGs (C_{12-C_{14}}) with ethoxylated fatty alcohol. By their eco- friendly nature, these mixed micelle are replacing the traditionally used phyto-sanitary products of nonyl-phenols. Their performance as a wetting agent with hard water tolerance and pH tolerance has been reported.
Chai et al. (2011) analyzed interaction of DNA with a CTAB/APG mixture and results indicated that the APGs stabilize the DNA/CTAB system.

2.5 Organization of thesis

To accomplish the research work the thesis is structured as follows:

Chapter 1 introduces and emphasizes the key components for the study of alkyl polyglucoside surfactants.

Chapter 2 describes the detailed review of relevant literature on alkyl polyglucoside surfactants to understand the chronological developments on the topic thoroughly. The literature which was highly relevant to the synthesis, physico-chemical properties, mixed micellization and soil washing studies has been focused.

Detailed description of materials and chosen research methodologies and the experimental techniques have been described in the Chapter 3.

Chapter 4 incorporates the synthesis and characterization procedure of alkyl polyglucoside surfactants and their interesting physico-chemical properties.

The mixed micellization behavior of synthesized alkyl polyglucosides with the commercially important cationic surfactants has been reported in Chapter 5.

In Chapter 6, a systematic investigation has been carried out to evaluate the soil washing capacity of synthesized alkyl polyglucosides and their efficiencies have been compared with the other commercial nonionic surfactants.

Finally, Chapter 7 provides conclusions of the performed research work as well as future scope of the present research work.