

sugar rings and restricted rotation around the glycosidic linkage make ALG molecules stiff. The rigidity of the chains further is due to electrostatic repulsion between the charged groups on the polymer chain and on ALG composition. It increases in the order  $MG < MM < GG$ ; therefore, G-rich ALGs generally form hard and brittle gels, while soft and elastic gels are produced by M-rich samples. Hence, the physicochemical properties and degree of polymerization of the ALG depend on the arrangement of these blocks [5].

## 1.4 Alginates and Their Properties

### 1.4.1 Gel Formation

Alginate can form gel independent of temperature as compared to other polysaccharides such as gelatin or agar. The ALG gels can either be ionic gels (formed by cationic cross-linking) or acidic gels (formed by acid precipitation).

#### 1.4.1.1 Ionic Alginate Gels

The ability of ALG to form ionic gel in the presence of multivalent cations is mostly desired in food industries. The process of binding of ALG to divalent cation is very specific, and the affinity of ALG toward cations is in the order  $Mn < Zn, Ni, Co < Fe < Ca < Sr < Ba < Cd < Cu < Pb$  [7, 8], and it depends on the number of G blocks present in the structure [9]. The cooperative binding of G block and divalent cations results in gelation of ALGs. The use of highly toxic cations such as Pb, Cu, and Cd is limited for practical applications, but less toxic cations like Sr and Ba have been reported to be used in cell immobilization applications at limited concentrations [10]. Calcium being nontoxic is widely accepted to form ionic ALG gels. Calcium-ALG gel is the most commonly used ALG gel. Interactions between Ca ions and G residues result in gelation of ALG, which leads to chain-chain association and to the formation of junction zones. The two G chains bind on opposite sides with the addition of Ca ions to the ALG polymer, which results in a diamond-shaped structure with a hydrophilic cavity. The oxygen atoms from the carboxyl groups form multicoordination with the Ca ions in the hydrophilic cavity. This tightly bound complex forms a junction zone that is shaped like an “egg box” (Figure 1.3). In this egg box, a 3-D network is formed by the binding of each cation with four G residues [11]. In case of Ca ALG gels, there should be 8 to 20 adjacent G residues in order to form a stable junction [12].