1. INTRODUCTION AND OBJECTIVES OF THE STUDY

Potato (*Solanum tuberosum* L.) is an economical and healthy food crop containing high starch and substantial amounts of protein, ascorbic acid and minerals (McCay *et al*., 1987). Over the last decade, a significant increase in production and use of potato crop in many different parts of globe has been reported, perhaps because of the increase of demand on potato and potato products. New technologies for food production and preparation have also great influences on potato consumption and potato production (Talburt, 1987; Scott, 2002).

Like many other food crops, whether prepared for table consumption or prepared as raw material for industrial purpose, potatoes also have to meet some quality criteria. Quality could be different depend on the processing condition and type of end products to be produced. Potato product quality is influenced in many ways by the raw material. Many attempts have been performed in order to meet desired quality of final products.

According to FAO food balance sheets, up dated 2004, the amount of potato available for consumption globally 202.013.202 metric tons, of which more than 10% (27.435.336 metric tons) was used for consumption in European Union (12 countries), and Germany alone used about 5.962.839 metric tons for consumption (FAO, 2004). The demand for fresh and processed potato in developing countries was also increase. An example of Indonesia, showed an increasing of available supply for consumption from 416.993 metric tons in 1990 to 801.560 metric tons in 2000, within which about 10% used for processed production with annual average growth of 24.8% (Fuglie *et al*., 2003).

Following harvest, potato tubers are often submitted to a long storage period, sometimes for 8 –10 months (Lisinska, 1989; Smith, 1987) in order to ensure the continuity of supply especially in potato-based industry. At harvest and for an indeterminate period thereafter tubers are placed in rest period, and even when stored under favourable condition for sprouting, tubers were physiologically dormant (Claassens and Vreugdenhil, 2000). On dormancy breaking the compositional alteration is likely to occur, as well as mobilization of components to favour the sprouting, which adversely affects the nutritional quality and processing

characteristic of tubers (Talburt *et al.*, 1987; Claassens and Vreugdenhil 2000). Losses during storage resulted in financial losses to potato processing industry, which normally relies heavily on stored tubers.

The growth and quality of harvested potato tubers are vary widely, depending on cultivation, climate conditions, soil conditions, varieties and management practices. Beside postharvest treatments, that have been reported to be successfully applied in order to maintain the quality of potato tubers, there is a growing interest on maintaining the quality through managing the development of plant during growing process, such as through fertilizer application. Fertilization has substantial effect on growth of potato plants and subsequently on potato yield and tubers quality during storage (Kolbe *et al*., 1995). It is important to note that type of fertilizers, applying methods, rates and forms of fertilizers also play an important role in determining the quality of harvested tubers.

Responding to many considerable debates about the value of applying calcium and considering the interaction effect of nutritious applied to soils used for potato production, there is a need to develop fertilizer management application in order to improve yield, tuber quality and processing quality, therefore this work was designed

1. to study the effect of combination of phosphorus, calcium and magnesium fertilizer on yield and selected tuber quality parameters
2. to investigate the effect of phosphorus, calcium and magnesium fertilizer on cell wall content and its fractions
3. to see the effect of phosphorus, calcium and magnesium fertilizer on pasting characteristic and some other functional properties.

The investigation was conducted on fresh harvest tubers and on tubers during extended cold storage in order to reveal whether the treatment would also influence the properties of stored potato tubers.

2. LITERATURE REVIEW

2.1 Potato Tuber Quality during Storage

Technologically, storage at low temperatures is one of methods normally used to retard the softening and sprouting process, and to maintained potato tuber quality (Burton, 1989; Chourasia and Goswami, 2001). During extended cold storage, however, potato tubers component are subject to change. It has been well documented that one of the major composition changes during storage was the decreasing of starch content of tuber. Cottrell *et al*. (1993) has investigated the starch degradation during storage by using cryo-scanning microscopy. They documented the physically breakdown of starch granules, and claimed that physically change in the surface of starch granules begin in early storage period and continue throughout the whole period of storage.

Previous study by Cochrane *et al*. (1991) supported by Cottrell *et al*. (1993), found that activity of enzyme alpha-amylase, beta-amylase and further starch debranching enzymes were increasing during the storage. The activity of enzymes are related to the declining of starch content and dry matter of tuber, and to the increasing reducing sugar content as end product of the hydrolysis process of starch. A considerable protein breakdown has also been noted by Davies and Ross (1987), along with the increase of proteolytic activity in tubers during storage.

Distribution of minerals was also changed during storage, especially prior to the onset of sprouting as a result of ions mobilization. There were a marked positively gradient of movement of phosphorus, potassium as well as magnesium toward the eyes and later set in the sprout (Decock *et al*., 1975). Large amount of phosphorus, potassium, some magnesium but little calcium were found in sprout.

Softening, which has also been referred as long storage effect of fruits and vegetables, is usually represent by decrease in the firmness of the tissue. Changes in the organ texture and properties are related to the changes in the composition and the structure of the matrix components. It is well known that change in texture of potato tubers is primarily related to the change in cell wall carbohydrate metabolism, due to the action of cell wall-degrading enzymes. This change led to the change of cell wall component, mostly of pectic substance and

hemicellulose polysaccharides, and subsequently resulting in disassembly of cell adhesion. Many studies supported that the degradation of pectic polysaccharides has a strong relationship with the decrease of the firmness of fruit tissue (Willats *et al.*, 2001a).

The changes in functional properties of potatoes during processing are highly dependent upon the composition of tubers including the cell wall. Biochemical and physiological changes occurred during storage have various effects on french fries colour and texture (Agblor and Scanlon, 2002), and on canned potatoes (Reid *et al*., 2000).

Knowledge about tuber and cell wall composition and its modification through post-harvest storage, therefore, is needed to ensure better handling and processing.

2.2 Cell Wall and its Relation to Utilization and Quality of Potato

Each cell is surrounded by cell wall, which provides support while the cell is growing and after differentiation is over, and the cell wall also offers protection against invasion by plant pathogen. Plant growth depends on changes in mechanical structure of cell wall, a process which could involve alteration in the structures of the matrix polysaccharides, pectic and hemicellulosic fractions, which serve as structural elements of cell wall (Darvil *et al*., 1980). Diverse roles have also been proposed for pectic polymers including the regulation of cell-cell adhesion, cell expansion, regulation of cell wall ionic status, mediation of wall porosity, a source of signalling molecules (cell-cell communication), and involvement in cell proliferation and cell differentiation (Darvil *et al*., 1980; Willats *et al.*, 1999).

The plant cell wall is a highly complex matrix containing cellulose, hemicellulose, pectins, structural protein and other components such as minerals. The ratio and exact composition of various wall components vary among plant species, cell types and even the neighbouring cells. Exposure to any of number of abiotic and biotic stresses alters the composition and structure of the cell wall.

In cell wall polymers, pectic polysaccharides, particularly polyuronides, have been known to be major constituent of the primary cell wall and middle lamella. Pectin matrix of plant cell wall is a complex mixture of homogalacturonan (HGA),

rhamnogalacturonans I (RG-I), and rhamnogalacturonan II (RG-II) (Willats *et al.*, 1999; Willats *et al*., 2001a; Willats *et al*., 2001b; O'Neill and York, 2003).

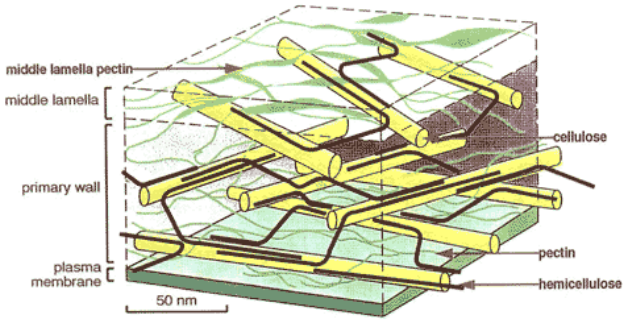

Figure 2.1 Plant cell wall structure (*http://www.ippa.info*)

The homogalacturonans are composed primarily of polygalacturonic acid, a homopolymer of 1,4 α-D galactosyluronic acid units. The carboxyl group of homogalacturonan (HGA) can be differentially methyl-esterified and/or acetylated. With HGA as a backbone, RG-I carries natural side-chain of predominantly 1,4-β-D-galactose and/ or 1,5-α-L-arabinose residues attached to the rhamnose residues of the backbone. Meanwhile, the RG-II contains diversity of sugars, at least 12 different monosaccharides, which attached to HGA as backbone (Fry, 1986; Sorensen *et al*., 2000).

Pectin methyl esterase (PME) catalyzes the removal methyl ester groups within the cell wall and leaving the free carboxyl group in place which can react with divalent ion, e.g., Ca^{2+} and Mg^{2+} , creating a cross-link between the HGA through the formation of Ca^{2+} and Mg^{2+} cross bridge in pectin, and creating more rigid structures and increasing the firmness (Fry, 1986; Tajner-Czopek, 2003). Therefore, calcium plays an important role in making the wall very coherent and providing stability and mechanical strength to the cell wall, and indirect role to keep the middle lamella intact. Extensive cross-linking with pectic polymers may restrict the access of hydrolytic enzymes to cell wall compounds, and influence the susceptibility of the tissue to pathogenic invasion (Fergusson, 1984; Siddiqui and Bangerth, 1996).

Major hemicelluloses are xylan and xyloglucan, which together with pectin are synthesized in Golgy apparatus. Xyloglucan, a major hemicellulosic component in dicotyledonous and non-graminaceous monocotyledonous plant, is composed of a linear β-1,4-glucan backbone with side chain of xylose (Xyl), galactose (Gal), fucose (Fuc) residue (Pauly *et al*., 1999; Fry, 2004).

Cellulose is composed of neutral, β-(1-4)-D-glucan chains, hydrogen-bonded together produces a strong linear ribbon structure, aggregates stable microfibrils, and forms the skeleton for both the cell and for the plant (Delmer, 1987; Fry, 2004). Cellulose and hemicellulose are assembled at different location and mediated by hydrogen bonds to form a network. Co-exists with other network consist of pectic polysaccharides, the integrity of the cellulose/hemicellulose network is considered strongly determine the integrity of the cell wall (Pauly *et al*., 1999; Whitney *et al*., 1999).

Different types of structural cell-wall protein have been identified, among which hydroxyproline-rich glycoprotein (HRGPs) or extension, praline-rich protein (PRPs), arabinogalactan protein (AGPs), and glycine-rich protein (GRPs) (Cassab, 1986; Showalter, 1993). Moreover Cassab (1986) proposed that the majority of the cell wall protein are cross-linked into the wall and probably have structural functions, and may also participate in morphogenesis. Extensin may be covalently cross-linked to some wall carbohydrate and also likely interacts with pectins, in which the positive charge of lysine and hystidine residues interact with negatively charged uronic acid of pectin, and this process was regulated by the cell wall pH and presence of Ca^{2+} (Showalter, 1993).

The available information about the cell wall are vary, depends on the variety and on method of extraction used for analysis. Jarvis *et al.* (1981) reported that mature potato contained 1 - 1.5 % cell wall of fresh material basis, of which pectic fraction made up to 52 %, NaOH-extracted hemicellulose around 9.5%, and 29.4 % cellulose fraction. Meanwhile, Braun (1989) found that cell wall of potato cv. Saturna consisted 11 – 20 % protopectin fraction, 20-59 % NaOH-extracted hemicellulose, and the remainder represent cellulose + lignin amounting to 31-64%. Moreover, she found that the composition could vary from one growing season to another.

Estimating the cell wall content is required not only in relation to nutritional attribute of the product, but also relating them to other properties of tubers, such as

storage characteristic of tubers as well as processing properties. Jarvis *et al*. (2003) reported that the cell walls of potatoes have an important role in maintaining freshness of potato tubers during storage and also influence the textural quality of many processed potato products.

Plant cell wall are implicated in changes in the structural and mechanical process of tubers during prolonged storage, and these changes influence the tubers quality and the time of storage for commercial uses. The cell wall pectin subjected to continuous modification, as have been studied on tomato (Tong and Gross, 1990), spanish pear (Martin-Cabrejas *et al*., 1994), banana (Kojima *et al*., 1994), and asparagus (Waldron and Selvendran, 1990). These studies have demonstrated that ripening and softening were accompanied by pectin solubilization. These changes were brought about through the action of cell wall hydrolases degrading various wall polymers. Enzymes such as polygalacturonases, pectinmethylesterase, β-galacturonase and glycanase played major roles in this process (De Veau *et al*., 1993; Lazan *et al*., 1995; Cheng and Huber, 1997; Ali *et al*., 1998; Hadfield and Bennett, 1998).

Softening has also been related to the activity of the hemicellulose and cellulose related enzymes. Regwell and Fry (1993) reported a wall swelling phenomena, which may be caused by changes in the cellulose/hemicellulose interaction during kiwifruit ripening, and found correlation between wall swelling and increase of xyloglucan endotransglycosylase (XET). Moreover, it was suggested that sweeling or loosening of the cell wall may be a factor in the release or solubilization of pectic polysaccharides.

Such degradation of cell wall components are also reflected in the changes in the functional properties exhibited by changes in viscosity, and its modification during processing has been used to improve the processing technology of fruit and vegetables towards a better properties of products (Kunzek *et al*., 1999).

It is well known that β-elimination process is responsible in degradation process of pectin, more over, Keijbet *et al*. (1976) have found that presence of calcium ions and addition of similar calcium ion could help to reach optimum stabilization against solubilization of pectin during boiling. In this study we used some aspects of physicochemical properties of flour prepared from freeze dried tubers to examine the effect of the change.