MINIMIZING POST HARVEST LOSSES IN POTATO TUBERS (*SOLANUM TUBEROSUM* L.) USING GAMMA IRRADIATION, MINT OIL, PACLOBUTRAZOLE AND THEIR RELATES UNDER UNREFRIGE-RATED STORAGE CONDITION

By

SOHA MOHAMED EL-SHERBINY ISMAIL
B.Sc. Agric. Sc. (Horticulture), Ain Shams University, 1989
M.Sc. Agric. Sc. (Veg. Crops), Ain Shams University, 2005

A Thesis Submitted in Partial Fulfillment

Of

The Requirements for the Degree of

DOCTOR OF PHILOSOPHY
in
Agricultural Sciences
(Vegetable crops)

Department of Horticulture
Faculty of Agriculture
Ain Shams University

2017

Approval Sheet

MINIMIZING POST HARVEST LOSSES IN POTATO TUBERS (*SOLANUM TUBEROSUM* L.) USING GAMMA IRRADIATION, MINT OIL, PACLOBUTRAZOLE AND THEIR RELATES UNDER UNREFRIGE-RATED STORAGE CONDITION

By

SOHA MOHAMED EL-SHERBINY ISMAIL
B.Sc. Agric. Sc. (Horticulture), Ain Shams University, 1989
M.Sc. Agric. Sc. (Veg. Crops), Ain Shams University, 2005

This thesis for Ph.D. degree has been approved by:

Dr. Fathy Abo El-Naser Abo Sedera ……………….....……
Prof. Emeritus of Vegetable Crops, Faculty of Agriculture, Banha University.

Dr. Ahmed Abou El-Yazied Abd El-Haffez ……………....………
Prof. of Vegetable Crops, Faculty of Agriculture, Ain Shams University.

Dr. Mohamed Mohamed Soliman …………………....…
Associate Prof. Emeritus of Vegetable Crops, Faculty of Agriculture, Ain Shams University.

Dr. Mohamed Emam Ragab …………………....…
Prof. of Vegetable Crops, Faculty of Agriculture, Ain Shams University.

Date of Examination: 30/ 9/ 2017

MINIMIZING POST HARVEST LOSSES IN POTATO TUBERS (*SOLANUM TUBEROSUM* L.) USING GAMMA IRRADIATION, MINT OIL, PACLOBUTRAZOLE AND THEIR RELATES UNDER UNREFRIGE-RATED STORAGE CONDITION

By

SOHA MOHAMED EL-SHERBINY ISMAIL
B.Sc. Agric. Sc. (Horticulture), Ain Shams University, 1989
M.Sc. Agric. Sc. (Veg. Crops), Ain Shams University, 2005

Under the supervision of:

Dr. Mohamed Emam Ragab
Prof. of Vegetable Crops, Department of Horticulture, Faculty of Agriculture, Ain Shams University (Principal Supervisor)

Dr. Mohamed Mohamed Soliman
Associate Prof. Emeritus of Vegetable Crops, Department of Horticulture, Faculty of Agriculture, Ain Shams University

Dr. Essam Ahmed El-Syed Ragab
Prof. of Biochemistry, National Center for Radiation Research and Technology, Atomic Energy Authority

ABSTRACT

Soha Mohamed Elsherbiny: Minimizing postharvest losses in potato (*Solanum tuberosum* L.) tubers using gamma irradiation, mint oil, paclobutrazole and their interaction under unrefrigerated storage condition. Unpublished Ph.D. Thesis, Department of Horticulture, Faculty of Agriculture, Ain Shams University, 2017.

This experiment was carried out on potato tubers at the Department of Natural Products, National Center for Radiation Research and Technology, Nasr City, Cairo, Egypt. The research aims to reduce losses resulting from the storage at room temperature and to reduce cooled storage costs of potato tubers using gamma radiation, mint oil and paclobutrazole treatments. Potato tubers cvs. Sponta and Diamont were treated with 100 Gy of gamma radiation, 5% of mint oil, 100 ppm of paclobutrazole during the two successive seasons of 2013/2014 and 2014/2015. Concerning Sponta tubers results showed that, tubers irradiated with 100 Gy and soaked in 100 ppm paclobutrazole scored the lowest values of weight loss, sprouting, shrinkage, decay and total weight loss, whereas, the highest values of weight loss were recorded to paclobutrazole + mint oil treatment. While mint oil treatment and mint oil + irradiation treatment scored the highest values of sprouting, shrinkage and decay. On the other hand, tubers irradiated with 100 Gy of gamma irradiation then soaked in 100 ppm of paclobutrazole had a higher content of starch and carbohydrates than other treatments. The highest values of protein were recorded with irradiation treatment and irradiation + paclobutrazole treatment. Irradiation + paclobutrazole treatment scored the highest value in specific gravity. GA and IAA hormones levels were higher after storage than before storage, whereas ABA showed opposite direction. The results of Diamont tubers showed that paclobutrazole treatment and radiation + paclobutrazole treatment scored the lowest value of weight loss. Paclobutrazole treatment, irradiation treatment and paclobutrazole + irradiation recorded the lowest values of sprouting and shrinkage with no decay. Irradiation treatment and paclobutrazole treatment recorded the highest percentage values of protein. Irradiation treatment and mint oil treatment scored the highest values of starch. Results of hormones can be summarized as general, the level for GA_3 and IAA were higher after storage than before storage, whereas ABA showed opposite results. The lowest values of total loss in both cvs Sponta and Diamont tubers were recorded with irradiation treatment, paclobutrazole treatment and irradiation + paclobutrazole treatment.

Key words: Potato tubers, gamma irradiation, mint oil, paclobutrazole, unrefrigerated and storability.

ACKNOWLEDGEMENT

Praise and thanks to Allah, the most merciful for directing me to the right way and provides me all I have.

I would like to express my deepest thanks and sincere gratitude to **Prof. Dr. Mohamed Emam Ragab,** Professor of Vegetable Crops, Horticulture Dept., Ain Shams University for his kind supervision, suggesting the problem, valuable advices, valuable guidance, continuous help and assistance during the preparation of this manuscript. This work benefited greatly from his efforts. I would gratefully acknowledge him.

Great thanks would be expressed to **Dr. Mohamed Mohamed SolimanAbd El-Maola** Associate Prof. of Vegetable Crops, Horticulture Dept., Ain Shams University, for his supervision and kind support during the course of investigation and in writing the manuscript. All the time, his efforts will always be remembered and I would like to say to his, from all my heart, thanks for everything.

I would like to extend my deepest gratitude to **Prof. Dr. Essam Ahmed Ragab**, Professor of Chemistry, National Center for Radiation Research and Technology (NCRRT), Atomic Energy Authority, for his generous help, valuable assistance and his encouragement during this study.

Special thanks are due to all the staff members in Horticulture Department, Faculty of Agriculture, Ain Shams University, for their cooperation and friendly atmosphere.

Thanks also would be given to the all my professors in the Natural Product Research Department, National Center for Radiation Research and Technology for their facilities that they offered to achieve my work specially and also my thanks to **Dr. Amr Mohamed Monir** and **Dr. Ahmed El-Hefny**, for their continuous and great help during this study

INTRODUCTION

Potato (*Solanum tuberosum* L.) is recognized as one of the most important vegetable crops for local consumption and exportation.

In Egypt, potato occupies about 405840 feddans produced about 4.8 million tons with an average of 11.8 tons/fed., according to **FAOSTAT (2013)**. Globally, Egypt is ranked as number twelfth among potato producers. The total exported quantities were 460 thousand tons in 2015 The exported Egyptian potato is mainly produced from winter season. Potatoes were first domesticated about 8000 years ago in South America and taken to Europe and the UK through Spanish conquerors in the sixteenth century (**Lutaladio and Castaidi, 2009**). According to the Food and Agriculture Organisation (FAO) statistics, the four biggest potato producing countries in the world rankings in 2015 were China, India, the Russian Federation and Ukraine which produced approximately half of the total world production 330 million tonnes (**FAO, 2011**).

Potatoes compete with rice and wheat as a cheap source of energy for human diet and they are a good supply of vitamins and minerals including C, B6, thiamine, riboflavin and niacin. Moreover, they contain appreciable levels of minerals e.g. phosphorus, magnesium, iron, calcium, potassium and various antioxidants (**Elfaki** and **Albsher, 2010 and Burlingame *et al*., 2009).**

After harvest, most of the potato tubers are stored for a short or longer time until being used or distributed to the markets. In reality, the storage period is sometimes longer than these potatoes spend in the ground. Potatoes for processing purposes have to be stored at a relatively high storage temperature, usually between 8 and 10 °C. High temperature promotes sprout development, tuber dehydration and shrinkage. Whilst low storage temperatures (2 – 4 °C) can delay sprouting they can also produce potato tubers with a high accumulation of reducing sugars (glucose and fructose), thus changing the potato taste and colour during frying (**Kyriacou *et al*., 2009 and Teper-Bamnolker *et al*., 2010**).

Sprouting of potatoes is a serious problem causing losses in stored potatoes, it is associated with undesirable changes including weight loss, loss of nutrient value, softening, a high susceptibility to bruising and enzymatic discolouration and increased levels of naturally-occurring toxicants, e.g. glycoalkaloids (**Teper-Bamnolker *et al*., 2010 ; Lu *et al*., 2012**). Most of these changes are perhaps due to the evaporation and transport of nutrients as energy into the sprouts.

In Egypt**,** One of the most important problems which face potato during storage is sprouting especially under unrefrigerated storage conditions. Preventing potato sprouting during storage could be using different methods i.e., cold storage, breeding, dipping in hot water, modified atmosphere, chemical materials and physical methods **(Mohammed, 2012).** One of these physical methods is ionizing radiation. Ionizing radiation like gamma radiation produced from the sources like Co-60 or Cs-137 preserve potato against sprouting or postharvest disease **(Asha *et al.,* 2011).** Appropriate use of irradiation can extend shelf life, reduce the requirement of chemicals for preservation and pest control, produce sterilized products (controlling the microorganisms) that can be stored without refrigeration, delay the ripening of fruits and vegetables and limit quality deterioration of stored tuber and bulb crops by preventing post-harvest sprouting (**Arvanitoyannis *et al*., 2009**).

There are some organic compounds such as essential oil of some herbs which retard sprouting of potato tubers like mint oil (**Coleman *et al*. 2001).** Oils of some herbs and spices –essential oils –have been shown to reduce sprouting in potatoes and can be applied to certified organic compounds. These compounds are volatile plant derivatives including spearmint oil, peppermint oil, and clove oil. These alternative compounds are not true “sprout inhibitors” that inhibit sprouting by interfering with cell division or some other biological process. Volatile oils and hydrogen peroxide are more correctly called sprout suppressant, as they physically damage developing sprout with a high concentration of the product in the surrounding head space in the potato storage **(Anshu, 2012)**.

Peppermint and spearmint oils applied in storage can be used as effective sprout suppressants. A wick application of these oils gave better sprout control than thermal or cold aerosol applications. For potatoes in bulk storage, mint oil can be volatilized into the air stream circulating through the potatoes by creating a wick of absorbent material over the mint oil reservoir. This creates a large surface area saturated with the essential oil for quick volatilization and distribution throughout the bulk pile. Both peppermint and spearmint oil must be applied with a sufficient concentration of the volatilized oil in the atmosphere of the storage to damage the sprouts **(Kleinkopf *et al*., 2003)**.

Some chemical compounds may be used to retard sprouting and prolonging dormancy period. **Xin *et al.* (2008)** reported that plant growth regulators are shown to play important roles in regulating tuber dormancy. In commercial storage, sprouting is primarily controlled by low temperature combined with chemical inhibitors, such as Chlorpropham (CIPC). Paclobutrazole is a triazole compound categorized as plant growth retardant, and is mainly used to control vegetative growth of plants in various species. Paclobutrazole was reported to retard sprout elongation **(Ranney *et al*., 1994 and Wiesman and Lavee, 1994).**

Therefore, the aim of this study was to investigate the effect of gamma irradiation, mint oil, paclobutrazole and their interactions for increasing the dormancy period of potato tubers under unrefrigerated storage condition.

REVIEW OF LITERATURE

Potato tubers are an excellent staple food due to its high nutritional value. This in addition to their relatively easy cultivation makes potato more and more important as a critical crop to feed an increasing world population. Tubers are mainly consumed fresh, generating a constant all year round demand and making long-term storage of tubers after harvest necessary. The maintenance of post-harvest quality is of vital importance to producers and processors. Demand for potato is increasing and is year-round. However, producing potato throughout the year is not feasible in most parts of the world, therefore, long-term storage is essential. Since potato tubers metabolically active even during storage, sprout growth occurs after a period of natural dormancy **(Viola *et al.*, 2007).** During storage, effective sprout control is essential to successfully store the potatoes and minimize losses. Sprouting can result in tuber weight loss due to water loss through the lenticels, reducing tuber sugar levels, increasing bruising susceptibility and production of toxic glycoalkaloids **(Hartmans *et al.*, 1995, Sonnewald 2001 and Börnke *et al*. 2007)**. To achieve effective sprout suppression, numerous studies have been conducted to gain a better understanding of the mechanisms regulating tuber dormancy, dormancy release and sprout development.

At the end of the dormant period, buds in the eyes of potato begin to grow and form sprouts. Generally, the apical eye begins to sprout first marking the beginning of apical dominance stage. Planting seed tubers with apical dominance often results in plants with single stems and hence reduced yields. Thereafter, the apical dominance stage, additional sprouts develop and the multiple sprouting stage begins. This is the optimum stage to plant seed tubers as they give rise to plants with several stems. At this stage, light promotes the multiple sprouting stage and to keep sprouts short and strong. Many factors influence apical dominance such as storage temperature management and desprouting **(Aksenova *et al.*, 2013)**. Storing tubers at low temperature (4°C) until the apical dominance stage is over and then increasing the storage temperature (above 15 °C) to promote sprout growth will result in multiple sprouting. In order to decrease the number of sprouts, maintaining high storage temperature (15-20°C) is recommended; this will promote apical dominance **(Classens and Vreugdenhil, 2000)**. Removing the apical sprout of the tuber may induce the formation of multiple sprouts; this lead to a uniformly sprouted tuber that produces several stems per plant. At the end of multiple sprouting stage, the potato seed tubers begin the senility stage. Old tubers should not be desprouted even when sprouts become long; they may have lost their resprouting capacity or may only form thin 'hair sprouts' **(Bamberg, 2010)**.

After tuber induction, potato tubers undergo a period of dormancy during which visible bud growth is inhibited. Sprouting leads to major quality losses of stored potato tubers. However, control of tuber sprouting is a major objective in potato breeding. No master regulator of potato tuber sprouting has been identified so far **(Sonnewald and Sonnewald, 2014)**. It is pointed that sugar content is one of the important parameters determining the sprouting of seed potatoes **(Vreugdenhil and Struik, 2006, Barani *et al.*, 2013)**.

Potato tubers could be stored in controlled or rudimentary conditions. Under rudimentary conditions, such as store rooms of small farmers or houses; control of humidity and temperature could not be achieved. Respiration of tubers during storage and breakdown of dormancy during storage result in early sprouting and loss of nutritive value of tubers **(Suhag *et al.*, 2006)**. Dormancy also leads to physiological aging of tubers resulting in loss of weight and quality for fresh market tubers and also leads to yield losses if these tubers are used as seed tubers for planting **(Yosuke *et al.*, 2000, Suhag *et al.*, 2006 and Katundu *et al.*, 2007)**. The method used to break dormancy depends on facilities and chemicals available as well as the genetic characteristics of the breeding materials and varieties to be treated **(Ezekiel and Singh,**

2003). The most common temperature treatments are the heat, and the cold shock plus heat. The chemicals used in dormancy breaking often fall within the following categories: respiratory inhibitors, sulfhydryls, anaesthetic or end products of glycolysis. In addition, some hormones (gibberellic acid, bromoethane) are used to improve sprout growth of seed potato **(Muthoni *et al.,* 2014)**.

The review of literature could be devided into the following subjectes as follows:-

2.1 Effect of gamma irradiation:

Application of gamma irradiation is a well-known method to eliminate or inactivate the spoilage causes with no adverse effects on nutritional and sensory quality of foods (**Bidawid *et al.,* 2000**). Its use is gradually increasing worldwide, (**WHO 1999**). **Arvanitoyannis *et al.* (2008)** indicated that irradiation on potato tubers inhibited sprouting and reduced the weight loss. Otherwise, the application of irradiation may be an alternative treatment for controlling undesirable changes in potatoes during long-term storage. Appropriate use of irradiation can extend shelf life, reduce the requirement of chemicals for preservation and pest control, produce sterilized products (controlling the microorganisms) that can be stored without low temperature application, delay the ripening of fruits and vegetables and decrease quality deterioration of stored tuber and bulb crops by preventing post-harvest sprouting **Wang and Chao, 2003)**.

Doses between 50 and 150 Gy are recommended for sprout control of tubers and in dormant state shortly after harvest **(Majd and Ardakani, 2003)**. **Frazier *et al.* (2006)** reported that sprout suppression was achieved with doses of 40 to 50 Gy while higher doses caused undesirable increases in reducing sugars in the tubers. Besides, **Singh and Kaur (2009)** suggested that irradiation during the dormancy period of tubers is the most effective for sprout control. Other study indicated that early irradiation and higher irradiation levels significantly decreased sprouting, percent weight loss and specific gravity of tubers. In addition, the loss of ascorbic acid and the contents of reducing and non-reducing sugars significantly increased by delay in irradiation whereas the content of sugars and ascorbic acid level decreased by irradiation. Besides, the loss of firmness became clearer during five months storage in non-irradiated tubers.

Joshi *et al.* (1990) showed that irradiated potatoes stored at 15°C for 6 months had lower sugar levels than control tubers stored at 2–4°C. Irradiation induced softening and some physical damage was reported for number of fruits and vegetables by many researches, **Prakash *et al.* (2002)**, **Rastogi and Raghavarao (2004)** and **Rastogi (2005)**.

Irradiation has been recognized to be a means of sprout inhibition since the 1950s in numerous countries. The use of gamma rays or low energy electrons can effectively inhibit sprouting of potato tubers through penetration of these energies into the surface of the tuber where the eyes of the potato are located. Advantages of this treatment are long-term suppression of sprouting and little chemical residue thereby promoting potato safety. However, using irradiation to inhibit sprouting is very limited in the potato industry, it necessitates many facilities and is costly, which restricts the use of the technology. In addition, it is known to affect the molecular size of potato starch leading to degradation of the polysaccharide chains. Many countries restrict using this method on food **(Kumar *et al.*, 2009, Saraiva and Rodrigues, 2011and Lu *et al.*, 2012).**

2.1.1 Effect of gamma irradiation on physical characters:

Kubin (1984), using 60, 100 and 150 Gy of gamma irradiation on potatoes, found that the weight losses were on average higher in irradiated potatoes than in the control group. The development of storage diseases was found to be more dependent on previous gathering and sorting, in some species it increased after irradiation but in others it dropped after the 100 Gy dose.

Picha (1986c) reported that the contribution of respiration and transpiration to total weight loss was determined during curing and storage in 6 cultivars. Respiration rate was highest at the day of harvest, decreasing during curing and continued to decrease at a slower rate during the first few months of storage, then it remained constant. Respiration contributed more to total weight loss during the latter periods of storage than during curing or the first months in storage. Transpiration, however, was the major source of weight loss. The highest rate of weight loss occurred during curing, followed by a gradual rate of weight loss during storage.

Tolbert &Loretan (1986) subjected the roots of Georgia Jet and Jewel sweet potatoes to irradiation immediately after harvest and before curing, immediately after curing, or after curing plus 3 months of storage. Storage was at 14 to 16ºC with 85 – 90% RH. Roots were examined at different stages of storage over 9 months for sprouting, rot development, flesh color, texture and moisture. It was found that sweet potatoes should never be irradiated prior to curing at doses up to 0.20 k Gy. Nutritive qualities of moisture, texture and color all changed to one extent or another with increased storage time. Irradiation speeds up the process of cell wall collapse and accumulation of cytoplasmic depris, but this also occurs later in the control. Radiation effects on proteins are very small up to a dose of 0.20 k Gy, and irradiation of the root caused accumulation of new proteins while impairing the formation of others.

Yakubu (1986) studied the effect of gamma radiation and storage time on sprouting, rotting, changes in nutritional composition and sensory quality of Georgia jet sweet potatoes. All radiation doses used in the study inhibited sprouting. Sweet potatoes were severely injured at doses of 1.5 and 2.0 k Gy and these doses affected their storage life and sensory quality. There was no significant difference in nutrient composition of