Journal of Agricultural Technology 2011 Vol. 7(5): 1211-1222
Available online http://www.ijat-aatsea.com
ISSN 1686-9141

Effect of four primary tillage machines on some of qualitative properties of potato tubers

M. A Ghazavi*, B.Hosseinzadeh, A. Lotfalian

Department of Mechanics of Farrn Machinery, Shahrekord University, Iran.

M.A. Ghazavi, B.Hosseinzadeh, A.Lotfalian (2011) Effect of four primary tillage machines on some of qualitative properties of potato tubers. Journal of Agricultural Technology 7(5): 1211-1222.

Due to importance of potato production and various factors affecting quality production, experiments were conducted at the research farm of Khurasegan Islamic Azad University, Isfahan. The experiments were carried out as completely randomized blocks design with four treatments using moldboard, disk, improves disk, and chisel plows. Results showed that the effect of tillage machine type on moisture percentage, dry material, density, different sugars (carbohydrates), pH and organic acids of tuber at 5% level of probability were not significant compared and all the measured parameters were at an acceptable range. The Duncan multi-domain test at 5% level of probability showed that there is no significant difference between the effect of using improved disk plow and moldboard plow for most of measured characteristics. However, in some cases the effect of disk plow was superior. Therefore, the improved disk plow can be expressed a good substitute for the moldboard plow.

Key Words: Tillage, Potato, Physical Properties, Improved Disk Plow.

Introduction

Among world's food products, potato after wheat, rice, and corn is the fourth well-known product. The annual production of potato is about 307 million tones around the world (Fennir, M.A. 2002). Increasing population and limitations of farm lands are the reasons which have made researchers focus on potato mechanization (Rembeza, J. 1993; Bentini, M. 1992, Bolandi, A. R 2008). Mechanization include land preparation, planting, cultivating, harvesting, and also post-harvest issues, all of which have influence the choice of methods of production, storage, processing and qualitative aspects (Ekeberg, E. 2002; Gupa, M.L. *et al.,* 1994). In fact, each progress in mechanization can influence quality and quantity of potato production (Bentini, M. 1992; Carter, M.R. *et al.,* 2001, Ghazavi .M.A *et al.,* 2010).

One of the main purposes of tillage is to preserve and maintain a proper amount of clods in soil, avalability clods causes, the roots to penetrate and

* Corresponding auther: M. A Ghazavi,e-mail: mghazavi@gmail.com

develop better into soil, maximum amount of water is maintained in soil and consumed by plants and the surface particles can resist better against rainfall and prevent surface hardening and maximizing moisture maintenance of soil. The other benefit of it is a suitable bed for seeding which minimizes the erosion caused by water-flow and prevents from breakage of nutrients-carrying clods which are also carried by water moreover soil particles resist better against soil compaction caused by trailers and other farm machinery wheels (Richey, C.B. *et al.,* 1962). There is no standard method for preparing soil bed for potato but obviously minimizing tillage practices which economizes time and energy consumption and reduces soil compaction, is useful. In soils that potato grows in them there should be a sufficient amount of plant remnants mixed with soil, so that the planting machine could work easily in soil. The level of required tillage depends on the soil and machinery type. The soil should be sufficiently loosened so that the planter shoe would penetrate easily to the preferred depth and the also the listers would be able to develop a ridge from loosened soil on the seed. In the most common tillage method, during spring or fall the plants remnants are mixed with soil then during spring a disk harrow is used to break big clods. If needed for the third time a spring harrow is used to prepare the seed bed which mixes fertilizer with soil (Skorupinska, A. et al. 1991; Bolandi, A.R. 2007). In order to perform farm practices for some products such as potato, various devices are designed and manufactured including moldboard plow, automatic and semi-automatic planters, different cultivators, and harvesters (Balbach, F.W. *et al.,* 1992). Also in different countries several researches has been carried out in this field and different quantitative and qualitative aspects of mechanization effects have been evaluated (Fillippini, P. 1994; Sukra, A.B, *et al.,* 1995) and results concerning product increase (Garcia – Pardo, E. 1995, Ghazavi.M.A *et al.,* 2010) and improvements in product quality (Feck, W. 1991; Gupta,V.K. 2003) have been reported. Also in Iran mechanization is being discussed for long and in order to bring into practice many devices been imported or manufactured inside (Ghazavi, M.A. 1996; Ghazavi, M.A. 1997) which are being used for farming in many regions in country that these devices are not without defects.

One the most important and most consumed products derived from potato is potato chips which its color is one of the main parameters for consumers. If potato color darkens during production, is a sign of non-enzymic dark spot which is called Mailard(Leszkowait, M.J., *et al.,* 1990). In this reaction the reduced sugars and amine acids and peptides and proteins are involved, and eventually they lead to production of dark colored melanin compounds which causes potato chips' color become dark (Hoover, E.F. *et al.,* 1963; Rashidi, T. 2004). Chips' color depends on different compounds of potato like total sugar, reduced and non-reduced sugar, and organic acids (citric acid and ascorbic acid). The existence of glucose even in low amounts in potato's dry material and high amounts of sucrose and lower pH accelerate these reactions and also tubers with high sugar content lead to undesirable and burnt flavor (Smith, O. 1977). Furthermore, the higher the density, dry material, and starch content of the tuber, the lower the oil absorption of the product and decrease the chance of being rancid (McComber, D.R. *et al.,* 1987). Researches show that the chips' color is highly related to the potato's amount of reduced sugar and sucrose content (Illeperuma, D.C.K. 1994). Chips' texture is related to its dry matter and when the dry matter is higher relative to the potato variety, the chips' texture becomes more rigid (Lisinska, G. *et al.,* 1989). Chips' quality depends on potato genetic properties and variety. Varieties with the ability to accumulate reduced sugar are not suitable for producing potato chips (Jakuzun, H., K. *et al.,* 1995; Jony, H.D. 1995). Chips producing countries use those potato varieties that instantly after harvesting and also after a period of storage, could produce high quality chips.

The potato mechanization is used in order to properly implement machineries, soil maintenance and optimized usage from soil, relative to climatic, geographic, and economical conditions of the country, various experiments should be carried out. According to their results, necessary suggestions should be made. Therefore, primary tillage machines including moldboard, chisel, disk, and improved disk plows were studied, evaluated and compared for their effects on quality of produced potatoes. After harvesting potatoes, the main factors were tested and measured moisture content, dry matter, density, various sugars, pH, starch, and organic acids. In this paper the following objectives were pursued to Introduce the best primary tillage method for preparation of potato planting bed and To study some of the effective properties on harvested tubers quality and comparing to their standard range. Compare the new tillage machine with the common machines and suggested the most proper one.

Materials and methods

In order to evaluating effect of primary tillage machines such as moldboard plow (P1), improved disk plow (P2), chisel plow (P3), and regular disk plow (P4), an experiment was conducted as a completely randomized block design in three replications and their effect on some of qualitative properties of potato tuber was evaluated and analyzed. The experiments were carried out at the location of Khatun-abad experimental farm of Khurasegan Islamic Azad University. The soil texture of the farm to the depth of 50 cm was averaged 40 % sand, 50 % clay, 10 % silt and the pH was 7.8. The average rainfall of this region is about 146.6 mm and the mean temperature is 16.5 °C, also the geographical location of it is 51.41 degree of eastern longitude and 32.42 degree of northern latitude. Three land pieces were allocated each one consisted of 4 plots with 50 m length and 4 m width to perform the experiments. The secondary tillage was uniformly practiced by a local hard-shank cultivator. Then in each block potato seeds which are Marfona variety and are grown in Faridan and are common in the region were planted by means of a semi-automatic planter. The plowing depth was about 20 cm, the planting depth 10 cm and the distance between two successive ridges was 75 cm. Potatoes were planted on top of the ridges and were uniformly irrigated instantly. Tubers were harvested separately and in order to measure moisture content, dry matter, density, various sugars, pH, and organic acids were transported to the laboratory.

In order to measure the potatoes density, tubers were weighed in air and while floating on distilled water and by means of Archimedes law, density value was calculated through the following equation (the denominator value of the fraction is numerically equal to the volume of displaced water): (1)

$$d = \frac{\text{Potato Weight in Air}}{\text{Potato Weight in water} - \text{Potato Weight in Air}}$$

In order to calculate the moisture weight of potatoes, a given amount of samples were dehydrated in an oven to reach to a constant weight. The amount of weight loss is equal to moisture weight of the sample (oven temperature was adjusted to 105°C). The porcelain capsules were cleaned and marked and were dried for about 30 minutes inside the oven, then they were cooled down at diskator and weighed. The capsule was weighed with a small glass rod as an agitator and 4-6 g of stuff was placed inside the capsule and homogenized with a small amount of water at the glass rod. The weight of capsule plus the glass rod and the stuff inside was measured. In case of highly moist samples, the capsules were passed through a hot water bath so that their additional moisture would vaporize. After placing in an oven at 101-105 °C in order to achieve a constant weight for at least 2 hours (preferably one night), the capsule was brought out of the oven and was cooled in a diskator. The capsule weight plus its contents was recorded after drying and moisture content and dry matter of the samples were calculated, assuming that the weight loss was only because of moisture removal. It should be mentioned that for better conduction of heat, a small amount of sand was added to the contents of the capsules. Moisture percentage was calculated through the following equation:

% of potato tuber moisture=$(w_2-w_3)/(w_2-w_1)$

Where, W_1 = empty capsule weight + (glass rod + sand), W_2 = capsule weight + potato sample + (glass rod + sand) before drying and W_3 = final capsule weight + potato sample + (glass rod + sand) after drying, The amount of dry matter is:
% dry matter = 100 - % of moisture.

Due to cheap price, availability and precision of Polarimeter method, it was used for measuring starch amount (Balbach *et al.,* 1992) and then the test was repeated by Refractometer method with no difference in results observed. In order to measure the reducing sugars, 5 g of potato samples containing sugar was weighed inside a beaker and about 100 mg of water was added to it. It was then agitated to solve all the contents into water. Then by using glass wool, it was refined inside a 250 mm volumetric flask. The beaker was washed inside the volumetric flask to achieve the volume. This solution was used for titration (Balbach.F.W, 1992). In order to measure total sugar, for hydrolysis of non-reducing sugars to reducing sugars, 100 mm of the solution by means of a pipette was poured inside an Erlenmeyer flask and 10 ml HCl was added and was boiled for 5 minutes. After being cooled down, the solution was reached to volume with 10% sodium hydroxide in existence of neutral phenolphthalein and inside a 250 ml volumetric flask. This solution was then used for titration of Fehling solution (Balbach.F.W, 1992).

Non-reducing sugars such as sucrose were calculating from the difference of total sugar and reducing sugars of the food (Balbach *et al.,* 1992). A Burette was filled with the sugar solution and with a pipette 10ml of A and B Fehling solution was transferred to a volumetric flask and 4 drops of 1% aqueous Methylin was added. The solution was boiled and during boiling it was titrated until the disappearance of the blue color. The titration was repeated on both Fehling A and B mixtures. 1-2ml of sugar solution, lesser than the approximate required amount, was instantly added to the boiling Fehling solution from the burette. 4 drops of aqueous Methylin indicator was added. Once more the solution was boiled and during this the sugar solution was added drop by drop to the Fehling solution to reach the final point (which is determined by disappearance of the blue color). The concentration of containing sugars of the solutions was calculated using the following factors:
1ml of Fehling Solution = 4.95mg glucose
1ml of Fehling Solution = 5.25mg fructose
1ml of Fehling Solution = 5.09mg inverted sugar
1ml of Fehling Solution = 7.68mg maltose
1ml of Fehling Solution = 6.46mg lactose
1ml of Fehling Solution = 4.75mg sucrose

The percentage of reducing sugars is determined from the following equation. Where, T, is the volume of consumed sugar solution prior to hydrolysis and, W, is the weight of used jam (g).

$$PS=(250\times 49.5)/(10\times T\times W)$$

PS=percentage of reducing sugars (based on glucose)

The percentage of total sugar was calculated from the following equation:

$$PS=(250\times 2.5(250\times 49.5)/(10\times T\times W)49.5)/(10\times T\times W)$$

In order to measure the pH, at first the grated potato extract was taken and then its pH was measured by pH meter (Metrohm) which was already calibrated by 4 and 7 and also 7 and 9 buffers. In order to standardize the color solution, 5ml ascorbic acid was added to a boiling tube by a pipette and was instantly titrated by color material solution [1]. After measuring the test variables, the data was analyzed by MSTAT-C software.

Results and discussion

Results showed that the measured variables from MSTAT-C are shown in Table 1. Which indicated that the effect of tillage machine type on measured properties was not significant at 5% level. Results showed a comparison of different treatments in Table 2 indicated that the effect of none of tillage tools is significant on pH, sucrose and total sugar at 5 % level. Tubers densitywas significantly higher at 5 % level in the chisel treatment. For starch, effect of improved disk plow was significantly higher than chisel and moldboard plows at 5 % level. For dry matter, the effect of moldboard and improved disk plows at level of 5 % was higher than the others and this was comparable with the result of moisture content in which the difference for moldboard and improved disk plows was significant at 5 % level. Also the previous result between dry matter and density of Marfona variety and other varieties had shown close relations (Bentini, M., 1992, Burchello.V. *et al.,* 1990). Former experiments showed no significant effect of primary tillage tool on tubers dry matter and density (Carter, M.R. 2001).

Table 1. The measured properties in different levels of primary tillage machines.

Source of Changes	Moisture	Dry Matter	Starch	Density	Sugar	Sucrose	pH
Primary Tillage Machine	4/701^{ns}	4/701^{ns}	0/030^{ns}	0/022^{ns}	0/0128^{ns}	0/018^{ns}	0/075^{ns}
Test Error	4/461	4/460	0/029	0/009	0/0104	0/005	0/089

* ns: non-significant

Table 2. Difference comparison of potato moisture, dry matter, starch, total reduced sugars, density.

Test variables /Tillagetool	Moisture %	Dry matter %	Starch	Reduced sugars	Density	Sucrose	pH
Moldboard	84/4a[1]	15/6b	5/27b	0/66a	1/07b	0/45a	5/69a
Improved disk	84/07b	15/93b	5/50a	0/71a	1/14ab	0/42a	5/83a
Chisel	82/4b	17/6a	5/22b	0/71a	1/23a	0/40a	5/97a
Disk	82/3b	17/7a	5/45ab	0/72a	1/07b	0/44a	5/82a

[1]Mean followed by a common letter are not significantly different by DMRT ta P=0.05

The average amount of potato moisture was about 75% of its weight. Potato tuber acts like a living organism after being separated from its plant and in begins metabolism in the vicinity of water. Water transports of the materials inside tuber and in high temperatures are protected it by being evaporated (Lisinska, G. *et al.,* 1989). The maximum amount of moisture inside tuber can be give up to 86.9 % (Bolandi, A. R. 2007). The amount of moisture shown in Figure 1 was in normal range and indicates that the planted variety (Marfona) maintains relatively high moisture content in all tillage conditions.

Thus the amount of dry matter was relatively low in all treatments. Considering that the least amount of starch in dry matter was 3.93 % and the maximum was 27.6 %. The amount of starch in samples shown in Figure 3. was not out of the normal range. The starch is the principal compound of tuber and builds the dry matter which increases during that growth season (Deobald, H.J. *et al.,* 1969). In primary stages of growth, the increase is at its highest and depends on the potato variety and environmental conditions, reaching its maximum at diffrent stages (Lisinska, G. *et al.,* 1989). The amount of tubers dry matter which is shown in Figure 2 was in its normal range. The percentage of potato dry matter varied between 13.1 to 36.8 % of which between 30 to 70% is consisted of starch and 2.1% is sugar (Lisinska, G. *et al.,* 1989). Starch is the main substance forming dry matter and can greatly affect the potato density. The other non-starch dry substances can also affect tubers density (Lisinska, G. *et al.,* 1989). The amount of potato dry matter increases during growth season and depending on the potato variety and environmental conditions at different times reaches its maximum amount (Cole, C.S. 1975).

The current results showed that the amount of the used variety starch was relatively low.

The density of samples which is shown in Figure 4. Which was also at its normal range which appears to be normal according the amount of dry matter. Density depends on diffrent factors including variety, potato maturity, planting factors like soil moisture, temperature during growth season, and light intensity (Lisinska, G. *et al.,* 1989) and has a straight relationship with potato dry matter and is varied from 1.0480 to 1.5100 (Lisinska, G. *et al.,* 1989). Density can be considered as a qualitative factor for choosing potatoes. then, the densities were relatively low in our syudy.

Although the amount of reducing sugar of all treatments was in its normal range and it was relatively low. Other dry substances such as sugar which are categorized as non-starch substances can affect tubers density. The amount of tuber sugar greatly varies and depends on variety, physiological stage, and maturity level of potatoes (Burchello, V. *et al.,* 1990). D-Glucose (0.15 to 1.5 % of fresh potato weight) and D-Fructose (0.15 to 1.5 % of fresh potatoes weight) Monosaccharides which are of non-reducing sugars can be found in potatoes (Gichohi, E.G. *et al.,* 1995). Sucrose (0.4 to 0.6% of weight) is a non-reducing sugar that can be found in potatoes. The three above mentioned sugars are the most important sugar fomation potato (Dellamonica, E.S. *et al.,* 1974), which are the result of the potato's sweet taste. The amount of sugar varies during growth season and during tubers maturity (Burchello. V., 1990). When a tuber reaches the state of complete maturity, its the amount of non-reducing sugar is decreased. The best harvest time for potato is when the ratio of sucrose to redusing sugar is at its lowest. The amount of reducing sugar in larger tubers is always lower than smaller tubers (Lisinska, G. *et al.,* 1989).Probably because of maturity phase completion. (Lisinska, G. *et al.,* 1989) The normal range of pH is 5.25 to 6.67 (Lisinska, G. *et al.,* 1989). The results showed that in different treatments the amount of pH in samples, which is shown in Figure 7 which was out of normal range as reported by Lisinska, *G. et al.,* 1989 and relatively low.

The results showed that the amounts of reducing sugars and sucrose was at their lowest possible levels in the variety. Considering the amount of dry matter was also low for the purpose of potato chips processing, the Millard process must be prevented. It is indicated that the amounts of mentioned substances for all cases are around acceptable and normal ranges but was relatively low. The result of potato production by using the improved disk plow (Iran Plow Tools) was identical to other standard tillage machines and had no positive effects. Therefore, it can be used as a new tillage machine inside Iran. Its usage due to lower energy consumption and faster performance in tillage practices (Ghazavi, M.A. 1997; Ghazavi, M.A. 2004) is more suitable than moldboard plow which is common in the region. Furthermore, since the moldboard plow is not suitable for arid and semi-arid areas, the new tillage machine no only creates no hard pan but also acts as a preserving device which decreases erosion and promotes moisture maintenance of soil and its availability for plants, thus increasing the fertility of soil. Hence the newly developed disk plow can replace moldboard plow through out the country (Ghazavi, M.A. 1997).

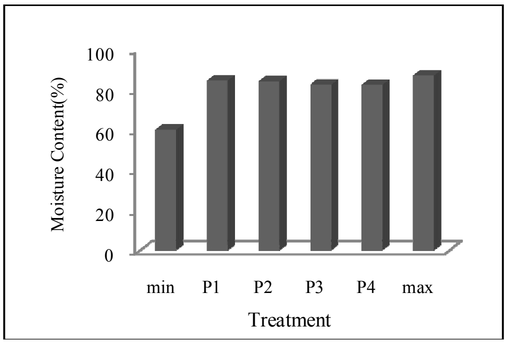

Fig 1. Potato moisture content in different treatments compared to normal range

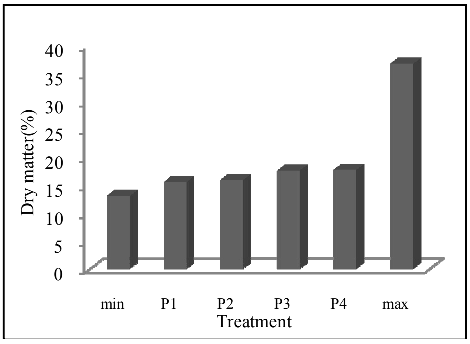

Fig 2. The amount of potato dry matter in different treatments compared to normal range

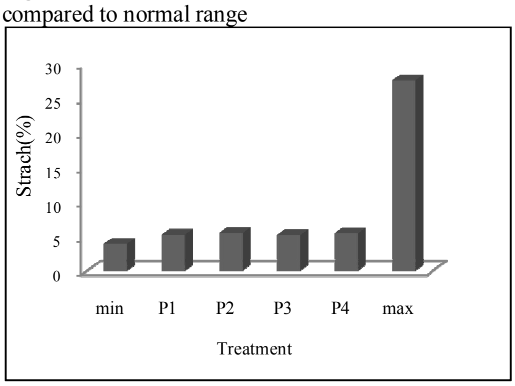

Fig 3. The amount of potato starch in different treatments compared to normal range

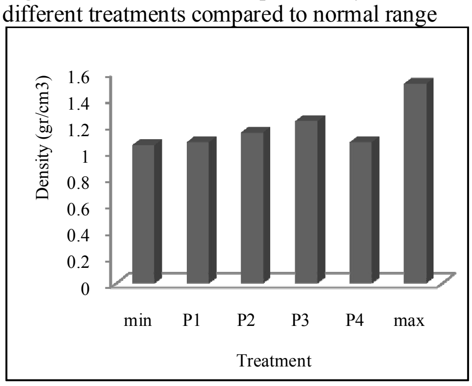

Fig 4. Density of different treatments in compared to normal range

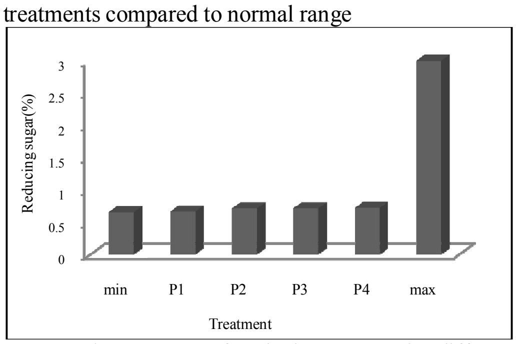

Fig 5. The amount of reducing sugars in different treatments compared to normal range

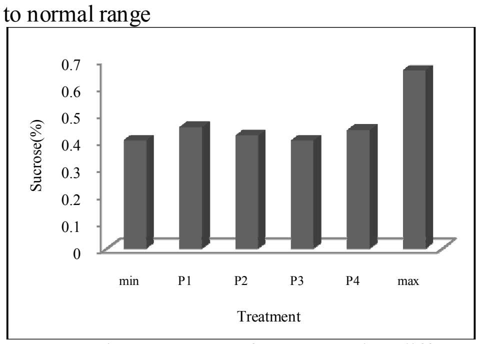

Fig 6. The amount of sucrose in different treatments compared to normal range

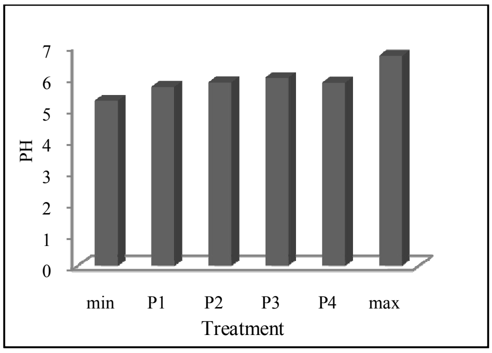

Fig 7. The amount of potato pH in different treatments compared to normal range

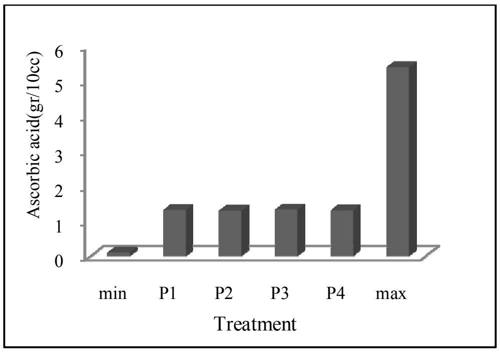

Fig 8. The amount of ascorbic acid in different treatments compared to normal range

Acknowledgment

The authors kindly thank the Department of Mechanical Farm Machinery, University of Shahrekord for their assistance in this project.

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(Received 15 February 2011; accepted 8 August 2011)