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Effect of Gamma Irradiation on Sprout Inhibition and Physical Properties of *Kufri Jyoti* Variety of Potato

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A B S T R A C T

Sprouting of potato is an undesirable phenomenon which results in weight loss and reduces its marketability. In this research, gamma radiation has been chosen as an effective tool to inhibit sprouting at comparatively higher storing temperature. Potato tubers of *Kufri Jyoti* variety were exposed to radiation dosages of 100 gray (Gy) and 200 gray (Gy) to study the sprout inhibition phenomenon and physical properties of this horticultural crop. The treated tubers were stored at 6°C, 15°C, and ambient temperature (minimum 17°C and maximum 40°C). The changes in the various physical quality parameters (weight, specific gravity, texture, and colour) were determined after five months of storage. Untreated samples kept in ambient showed very high weight loss of 27.4% and sprout wright of 4.23%. 200 Gy radiation was found to be detrimental for the tubers as discolouration in tubers was observed. The sample treated with 100 Gy radiation dose after 30 days of harvest and stored at 15°C temperature showed best results. Sprout weight and weight loss of this sample were found to be 0.62% and 4.47%, respectively. The peak forces of 1352 g and 12100.2 g were in firmness and shearing test, respectively clearly indicate that the texture of this potato samples were intact. The colour values (ΔL=52.2, Δb=41.2, Δa=7.25) obtained from colorimeter instrument were satisfactory enough to ensure customers' acceptance.

Introduction

Potato (*Solanum tuberosum*), commonly considered as the king of vegetables, has ranked fourth most important crop in India. The higher nutritional value of potato has made it superior vegetable and staple food all over the world. It is a short duration crop which is of greater food value maturing in a relatively shorter duration of time compared to cereal crops like rice and wheat.

In India, almost all states cultivate various types of potato depending on the agro-climatic conditions. According to the data from Horticulture Statistics Division, 68.93% share of total potato production of 2019 belongs to Uttar Pradesh, West Bengal, and

Bihar. Under tropical and sub-tropical conditions, major reasons behind the losses of potatoes are poor handling and storage. For potatoes meant to be used for table and processing purpose, sprouting is an undesirable characteristic and therefore, it is important to avoid sprouting in potatoes. Sprout growth begins at the end of dormancy period. Dormancy is a state in which tubers will not sprout even when placed under conditions ideal for sprout growth where the optimum temperature range being 18 to 20°C and relative humidity around 90% and stored in complete darkness. The duration of dormancy is normally counted from the date of harvest. Generally, dormancy period of *Kufri Jyoti* is 55 days (ICAR-CPRI, 2018). Once sprouted, potato starts losing weight, its' appearance is affected by shrivelling, and it loses marketability both for table and processing purposes. Shrivelled tuber loses vigour. Sprouting is influenced by several factors and the major factors that influence sprout growth are cultivar, temperature, humidity, light, concentration of CO_2 and O_2, and size of tubers. Temperature has strong influence on sprout growth. Generally, potatoes do not sprout when the storage temperature is less than 4ºC. Sprout growth increases with increasing temperature. Compared to the influence of temperature, humidity has only slight effect on sprout growth. When stored at 2.4ºC sprout growth does not take place. But tubers accumulate reducing sugars at low temperatures, a phenomenon referred to as cold-induced sweetening (CIS). The processing of these high sugar potatoes into crisps or fries leads to a dark brown to black product that renders them unfit for human consumption and causes a great loss to the processing industry (Rezaee *et al.*, 2011).

Some sprout suppression chemicals have been used on potatoes. The compounds generally used for controlling sprout growth are Alcohols, Acetaldehydes, Ethylene etc. Naphthalene Acetic Acid (NAA) and Methyl Ester of Alpha Naphthalene Acetic acid (MENA) have also been reported to considerably suppress sprouting. Presently, Chlorpropham CIPC (Isopropyl Carbamate) is the most commonly used sprout suppressant and only chemical registered in India for commercial application on potatoes. Treatment with such chemicals may produce many undesirable side effects.

Extension of storage life after treating with radiation ensures a steadier supply throughout the year and stabilizes the prices as reported by Brynjolfsson (1989). Gamma irradiation has been approved by Food and Drug Administration (FDA) as an effective technique to preserve and increase storage life of meat, fruits, vegetables, and spices. It is also used in some fruits and vegetables for supressing sprouting and delaying ripening process (Ganguly *et al.,* 2012). The process of food irradiation is coined as cold pasteurization as there is no noticeable temperature rise after this treatment (Ganguly *et al.*, 2012). Proper use of irradiation can increase shelf life, eliminate the need of chemicals for preservation along with pest control, produce products that can be stored for a longer period at ambient temperature, delay the ripening of fruits and vegetables as reported by Wierbicki (1986) and Arvanitoyannis *et al.,* (2009).

In this process, the sample to be irradiated is exposed to gamma rays from a radioactive source such as cobalt 60 (main source for gamma radiation) or caesium 137 or both under a controlled rate. The irradiation dose is usually measured in terms of Gray (Gy). One Gray (Gy) of radiation is equal to 1 Joule (J) of energy absorbed per kilogram of matter. It has been suggested by Truelsen (1960) that, potatoes after irradiation must be stored at 12°C for less weight loss in storage period and less sprouting. He added that weight loss of tubers stored at ambient condition increased from 4 to 34% during five months of storage following the sprout development. Sawyer and Dallyn (1961) observed same trend of reduction in weight loss in four potatoes varieties during storage at 10°C due to sprouting and shrinkage after irradiation of doses 50-150 Gy. Ezekiel *et al.*, (2008) showed that low doses (0.01 kGy and 0.05 kGy) of irradiation were as good as CIPC in suppressing sprout growth of potatoes stored at 8°C and 12°C.

In this study potato tubers of *Kufri Jyoti* variety were exposed to radiation dosages of 100 Gy and 200 Gy to study sprout inhibition phenomenon and physical properties of this horticultural crop. The treated tubers were stored at two different temperatures (6°C and 15°C) along with storage under ambient condition (minimum 17°C and maximum 40°C). The changes in the various physical quality parameters (weight, specific gravity, texture, and colour) and sprout growth were determined after five months of storage.

Materials and Methods

Experimental plan

Potato (*Solanum tuberosum*) variety *Kufri Jyoti* was cultivated at Haringhata, Nadia, West Bengal (22.96050 N, 88.56740 E), during the period of October 2018 to March 2019. Seed tubers weighing 50-100 g were planted on 20th October, 2018. Harvesting was carried out on 1st March, 2019.

The nomenclature of the samples was such that, (P-days after harvest-radiation dose-storage temperature); that means the sample P-15-200-6 denotes that it was irradiated with 200 Gy dose after 15 days of harvest and stored at 6°C storage temperature. ‘A’ and ‘UA’ were used for ambient storage and for untreated sample kept under ambient, respectively.

Gamma irradiation

Radiation was provided by a set of stationary Cobalt 60 source placed in a cylindrical cage in Gamma 5000 radiation chamber at RNARC (Regional Nuclear Agricultural Research Centre), BCKV, Mohanpur, Nadia, West Bengal. Specifications of Gamma radiation chamber 5000 are given in Table 1. Nearly 35 kg of potatoes were used for the purpose of our experimental study. 15 kg samples were exposed to irradiation at two specific doses on 15th day after harvest. Half of the sample that is 7.5 kg were given radiation doses of 100 Gy and rest 7.5 kg were given 200 Gy. Next, from 100 Gy irradiated samples, 2.5 kg were kept at 6°C storage temperature, 2.5 kg were kept under 15°C storage temperature, and rest 2.5 kg were stored under ambient temperature. Similarly, for the samples treated with 200 Gy irradiation dose were separately stored at those specific temperature conditions. Next, again nearly 15 kg of the samples were irradiated 30 days after harvest. Same procedure was repeated. 5 kg sample were kept untreated under ambient condition. The details of doses are given in Table 2.

Methodology for measurements of physical properties

Sprout weight

Samples were collected from storage room at the end of the storage period and the sprouts from the tubers were separated gently using sharp knife. Then the sprouts are weighed in an electronic weight machine with high sensitivity (make: A&D Weighing Solutions, model: FX-i, capacity: 300g, readability: 0.01 g). The sprout weights are expressed as the percentage of total tuber weight without sprout.

Weight loss

Weight loss of potato tubers was due to the process of respiration, converting sugar and starches to carbohydrate, carbon-di-oxide (CO_2), and moisture loss because of vapour pressure difference between the tubers and surrounding air. Percentage weight loss was expressed as (Mehta and Kaul, 1991; Nouri and Toofanian, 2001),

$$Percentage\ weight\ loss = \frac{(Initial\ weight - final\ weight)}{(Initial\ weight)} \times 100\% \quad ...(1)$$

Specific gravity

Specific gravity is the weight of the tuber compared to the weight of the same volume of water. The following formula was used for determining the specific gravity (Freeman *et al.,* 1998),

$$Specific\ gravity = \frac{Weight\ in\ air}{(Weight\ in\ air - Weight\ in\ water)} \quad ...(2)$$

Weight of the tubers were taken, and transferred to another tare weighing basket and weighed under water. The tubers sank in the water, so their weight is heavier than an equal volume of water. The weight measured is the difference between the weights of sample, and the weight of an equal volume of water. The volume of water absorbed by sprout was very less than the displaced water as the duration of test was very short (5-6 seconds). That's why it was not taken into consideration (Razaee *et al.,* 2011; Ferdous *et al.,* 2019).

Texture analysis

Texture is an important characteristic of product and it affects handling and processing which in turn influences shelf life and consumer acceptance. Texture of potato was measured by firmness test and shearing test. Firmness and shearing test were performed in texture analyser (make: Stable Micro Systems, model: TA.XT plus, force resolution: 0.1g) as suggested by Bourne, (1978).

Firmness test

In this study only peak force was measured during puncture test to correlate firmness of the tubers. The sample was placed on the platform of texture analyser and a 2 cm diameter cylindrical probe was used. The probe was attached with an Aluminium probe adaptor which was subsequently connected to the probe of the texture analyser. The test was done on the central part of the potato tubers on each face.

Shearing test

Shearing test was performed to determine the amount of force that was required to cut the tuber. HDP/BSK (Heavy Duty Platform/Blade Shearing Knife) was used as cutting instrument. In operation the blade was firmly held by means of a blade holder which was affixed above and descended into the slot of the Heavy Duty Platform (HDP) which both acted as a guide for the blade while providing support for the product. Specifications for firmness test and shearing test are given in Table 4.

Colour analysis

Since the skin colour of *kufri jyoti* variety of potato resembles white cream, in the study the changes in its colour parameters were studied with the colorimeter (model: Colorflex 45/0 spectrophotometer, manufacturer: Hunter lab). In the study the changes in colour of the tubers were observed for the specific samples treated with different radiation doses and stored under specific storage conditions.

A variety of colour scales or schemes are used to describe colour. In this study, 'Hunter ΔL, Δa, Δb system' was used to measure the colour of potato samples. The systems measure the degree of lightness (ΔL), the degree of redness or greenness (+/-Δa), and the degree of yellowness or blueness (+/-Δb). The "Δa" value measures redness when "positive" and greenness when negative. The "Δb" value measures yellowness when "positive" and blueness when "negative". The ΔL value measures lightness from 0 to 100 or the amount of light reflected or transmitted by the object (Hunter and Harlod, 1987).

Results and Discussion

Sprout weight

Irradiation played a major role to inhibit sprouting for five months of storage period. Sprout weights of samples are given in Table 5. The untreated sample had a sprout weight percentage of 4.3%, whereas for all radiated samples, treated with different doses showed sprout percentage in the range 0.56-0.89%. That means, gamma irradiation was able to inhibit sprouting by affecting the mitotic activity and the indole acetic acid synthesis (Nassef and El-Korayf, 2003). From Table 5, it can be found that, irradiated samples kept in ambient temperature showed higher sprout weight percentage. For example, samples irradiated with 100 Gy after 30 days of harvesting and kept in ambient showed 24.39% higher sprout weight percentage than samples irradiated with 100 Gy after 30 days of harvesting and kept at 15°C. Sprout weights of all the treated samples kept at 6°C and 15°C storage temperature were in the range of 0.56-0.62%. This clearly indicates that the treating with gamma radiation (both 100 Gy and 200 Gy doses) followed by storing at low (both 6°C and 15°C) was very much effective to inhibit sprouting.

Weight loss

Potato tubers lost weight in the process of respiration and during conversion of sugars and starches to carbohydrate, carbon-di-oxide (CO_2) and water. Tubers lost moisture because of vapour pressure difference between the tubers and surrounding air. The intensity of the dehydration and respiration process were significantly lower in irradiated potatoes (Fiszer *et al.,* 1985).

Table 6 shows the weight loss (%) of the samples after the storage period. Weight loss was maximum in case of untreated tubers, whereas weight loss in case of tubers treated with 100 Gy irradiation dosage was found to be much lower. Again there was greater weight loss in irradiated potatoes which were kept at 15°C than that of kept in 6°C. It might be due to higher respiration rate and increased membrane permeability (Takano *et al.,* 1974). Interestingly, the tubers exposed to 200 Gy irradiation showed tendency to rot and higher weight loss. This could be due to incomplete healing of wounds in irradiated potato. The wound-healing process involves suberization i.e. deposition of suberin, a lipid phenolic polymer on the cell layers below the wound surface, followed by formation of wound periderm. Both wound-induced periderm formation and sprouting involve mitotic activity and cell division (Thomas, 1982; Thomas and Delincee, 1979). This suberization process might be affected by 200 Gy dose irradiation. Irradiation with early date of irradiation increased weight loss. For example, samples treated with 100 Gy radiation after 15 days of harvest and stored at 15°C temperature showed 8.59% higher weight loss than samples treated with 100 Gy radiation after 30 days of harvest and stored at 15°C temperature. The samples treated with radiation but stored in ambient showed a significantly less weight loss compared to untreated samples kept in ambient. For example, weight loss of P-30-100-A sample was less than P-UA sample by 73.54%.

Specific gravity

Specific gravity of 1.085 was recorded just after harvesting. Table 7 shows the specific gravity of samples after storage period. It is obvious that specific gravity decreased after storage of five months. Only 0.83% change in specific gravity was detected in case of tubers treated with 100 Gy after 15 days of harvest and stored at 6°C, whereas tubers treated with 100 Gy after 15 days of harvest and stored at 15°C showed 1.75% change in specific gravity. This indicates that specific gravity decreased more at higher storage temperature. The specific gravity of the sample irradiated with 200 Gy after 30 days of harvest and kept at ambient temperature showed highest (2.12 %) change in specific gravity among all irradiated samples, whereas samples left untreated in the ambient condition recorded 5.99% change in specific gravity. It can be seen that samples stored at lower temperature showed comparatively less change in specific gravity for similar treatments.

Texture analysis

Self-generating graphs were obtained from texture analyser instrument. For example, puncture test (firmness) curve of sample P-30-200-6 and shearing test curve of sample P-30-200-15 are shown in the Fig. 5. The peak values of these curves denote firmness and maximum force needed to cut, respectively. The peak forces for all the samples are given in Fig. 6.

Generally, less force is needed to penetrate and cut a soft and shrivelled tuber. It can be observed from Fig. 11 that, storage temperature, irradiation doses, and date of irradiation have affected the firmness of the potato samples. Highest peak force was observed for the samples irradiated with 100 Gy after 30 days of harvest and stored at 6°C storage temperature. Lower peak forces from both firmness test and shearing test of 200 Gy irradiated samples than 100 Gy irradiated samples clearly indicate comparatively intact skin of 100 Gy treated samples. The untreated samples stored under ambient condition showed very soft nature. The peak force of firmness test and shearing test of those samples were 39.4% and 44.99% lower that P-30-100-15. This indicates the potatoes were shrivelled and lost its' firmness drastically. Samples irradiated with 100 Gy (stored at 15°C) after 15 days of harvest had 9.26% and 4.21% lesser peak force values in firmness test and shearing test, respectively than that of samples irradiated after 30 days of harvest. Interruption of wound healing process for early irradiation might be reason behind this. Storage temperature also affected firmness of potato sample. Storing in lower temperature resulted in higher firmness of tubers. The samples irradiated with 100 Gy after 30 days of harvest, reflected a decrease by 13.24% and 6.67% in peak force of shearing test for change in storage temperature from 6°C to 15°C and 6°C to ambient, respectively. This can be correlated with the weight loss at higher temperature. Weight loss and reduced membrane permeability caused reduction in peak force in firmness and shearing test.

Colour analysis

The colour values of samples are given in Fig. 7. Generally, skin colour of *Kufri jyoti* variety is creamy white or light yellow. ΔL value measures the lightness from a range 0 to 100 indicating the amount of light reflected or transmitted by the object. The higher the value of ΔL implies that the object is brighter reflecting most of the incident light. When the samples were physically inspected, it was noticed that, the samples irradiated with 200 Gy seemed to be darker and the tuber got discoloured, the skin turning into dark black in most of the tubers for both early and late radiation doses. The colour values after experiment confirmed this observation. The samples, treated with 200 Gy and kept in ambient radiation dosage, were darkest and showed lowest ΔL value of 32.16. Even untreated samples kept under ambient condition showed 35.92% higher ΔL value than this. P-30-100-6 samples had 2.25% lesser ΔL value than P-15-100-6. Increase in storage temperature from 6°C to 15°C keeping other parameters unchanged, caused reduction in brightness. If the samples irradiated with 100 Gy after 30 days of harvest are considered, ΔL value decreased 4.55% with change in storage temperature from 6°C to 15°C. The same was found to be 6.74% for change in temperature from 6°C to ambient. But this reduction was more prominent in the samples irradiated with 200 Gy. Samples irradiated with 200 Gy after 15 days of harvest showed a decrease of ΔL value by 18.48% and 25.85% with a change in storage temperature from 6°C to 15°C and 6°C to ambient, respectively. The positive value of Δb denotes the yellowness. Here the sample P-30-200-A had least yellowness whereas the sample P-30-200-15 is in slightly better condition than P-30-200-A. Same trend was found in P-15-200-A and P-15-200-15. Thus, it can be concluded that when the samples were irradiated with 200 Gy radiation dose the skin darkened and created some black spot initially and this increased with storage temperature. On the other hand, if the 200 Gy irradiated samples were kept at 6°C the problem of skin darkening could be controlled to some extent. The tubers irradiated with 100 Gy preserved natural colour in case of all the storage temperatures.

Table.1 Experimental plan

Variables	Levels	Values
Common Parameters		
Variety	1	*Kufri Jyoti*
Planting system	1	Ridge and furrow
Independent Parameters		
Radiation dose	3	0, 100, 200 Gy
Days after harvest	2	15, 30 days
Storage temperature	3	Ambient (minimum 17°C and maximum 40°C), 6°C, 15°C
Dependent parameters		
Sprout weight		% of total tuber weight
Weight loss		%
Specific gravity		
Texture analysis		Peak forces (g) in firmness and shearing test.
Colour analysis		ΔL, Δb, Δa

Table.2 Specifications of Gamma Chamber 5000

Irradiation volume	**5000 cc**
Size of sample chamber	17.2 cm (dia.) × 20.5cm (height)
Shielding material	Lead & Stainless Steel
Weight	5600 kg
Size	125cm ×106.5cm ×150cm
Timer range	6 sec onwards

Table.3 Specifications of applied dose in the experiment

Dose	**100Gy**	**200Gy**
Temperature	34.8°C	35.9°C
Radiation time	50 sec	1 min 40 sec
Dose rate	7.235 KGy/h	7.235 KGy/h

Table.4 Specifications of firmness and shearing test

	Firmness Test	**Shearing Test**
Test mode	Compression	Compression
Pre-test speed	2 mm/s	2.00 mm/sec
Test speed	1 mm/s	2.00 mm/sec
Post-test speed	10 mm/s	10.00 mm/sec
Target mode	Distance	Distance
Distance	5.00 mm	12.00 mm
Strain	10%	10%
Trigger type	Auto(Force)	Auto(force)
Trigger force	20 g	5.00 g
Probe model no	P/2	HDP/BSK
Probe type	2 mm diameter, 3.14 mm^2, stainless steel	Blade set with knife
Points per second	200	200

Table.5 Sprout weight of samples

	Sprout weight (%)
P-15-100-6	0.56
P-15-100-15	0.59
P-15-100-A	0.78
P-15-200-6	0.56
P-15-200-15	0.59
P-15-200-A	0.8
P-30-100-6	0.59
P-30-100-15	0.62
P-30-100-A	0.82
P-30-200-6	0.57
P-30-200-15	0.6
P-30-200-A	0.89
P-UA	4.23

Table.6 Weight loss of samples

	Percent weight loss (%)
P-15-100-6	3.89
P-15-100-15	4.89
P-15-100-A	7.66
P-15-200-6	6.16
P-15-200-15	7.31
P-15-200-A	8.56
P-30-100-6	3.36
P-30-100-15	4.47
P-30-100-A	7.25
P-30-200-6	5.68
P-30-200-15	6.91
P-30-200-A	8.13
P-UA	27.4

Table.7 Specific gravity of samples

	Specific gravity
P-15-100-6	1.076
P-15-100-15	1.066
P-15-100-A	1.051
P-15-200-6	1.075
P-15-200-15	1.062
P-15-200-A	1.05
P-30-100-6	1.073
P-30-100-15	1.059
P-30-100-A	1.049
P-30-200-6	1.072
P-30-200-15	1.061
P-30-200-A	1.047
P-UA	1.02

Fig.1 Sprout weight determination

Fig.2 Specific gravity determination

Fig.3 Firmness test

Fig.4 Shearing test

Fig.5 Self-generating curves from texture analyser instrument

(a) Puncture (firmness) test

(b) Shearing test

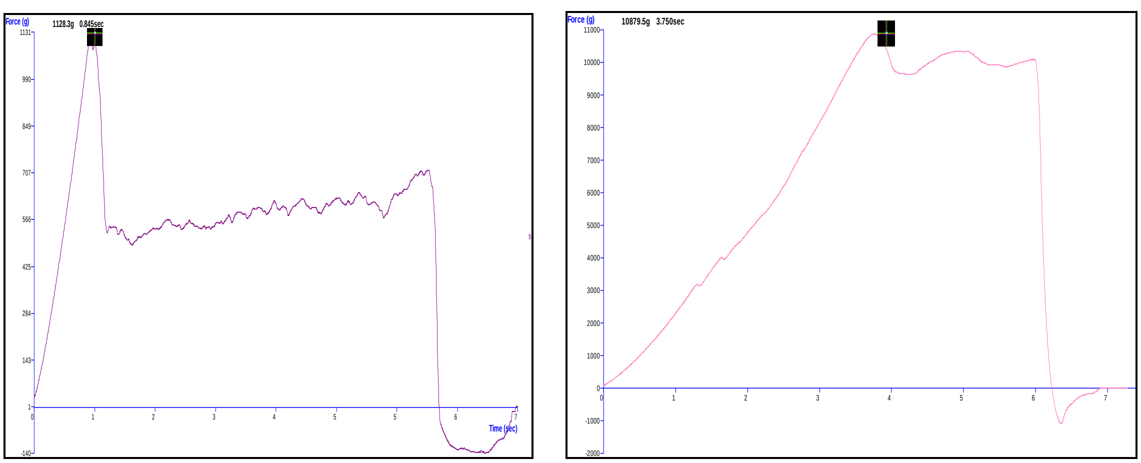

Fig.6 Peak forces in firmness and shearing test

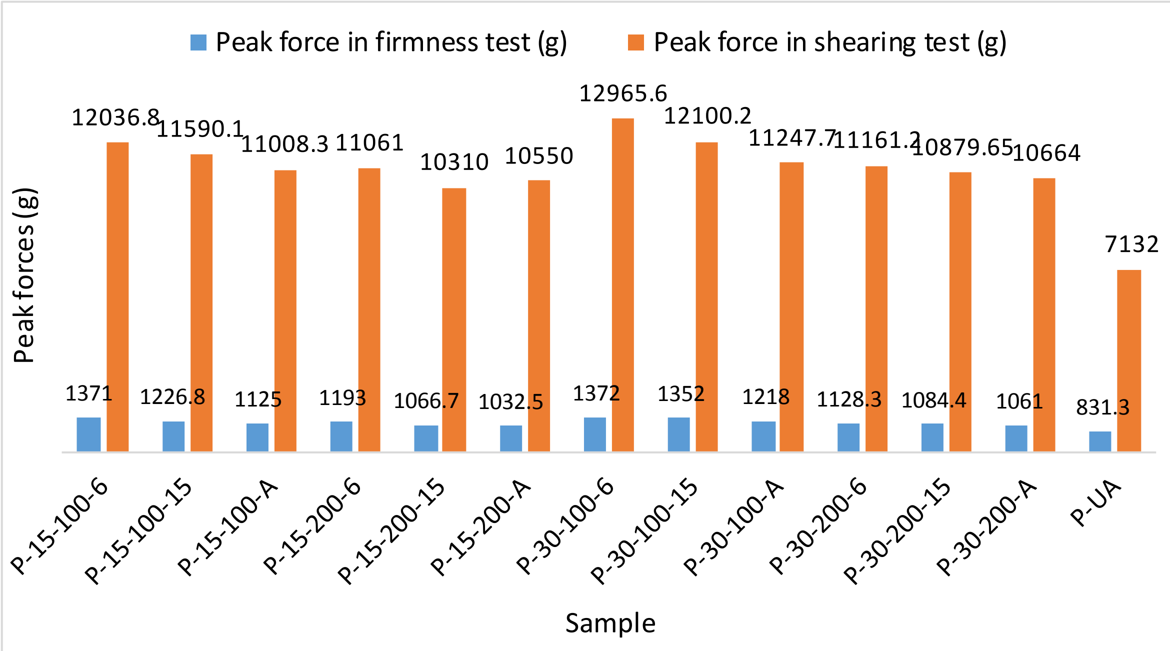

Fig.7 Colour values of samples

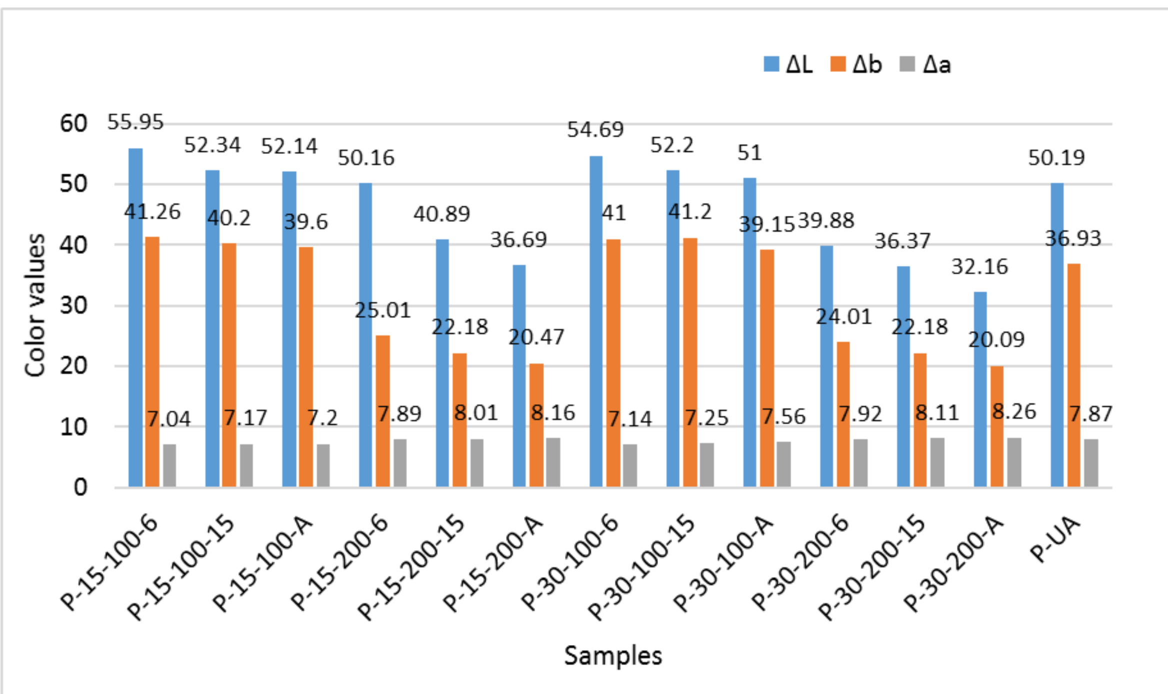

Fig.8 Colour comparison on P-15-100-15 and P-15-200-15

Some P-15-100-15 & P-15-200-15 samples are kept separately in Fig. 8. It is easily understandable that, upper side tubers (P-15-200-15) having very dark skin colour and some of them started rotting. Lower samples (P-15-100-15) maintained natural skin colour. This darkness is caused in case of higher dose irradiation due to the browning of tissues around the cortex region and vascular bundles of tubers irradiated (Ogawa *et al.*, 1969). Partial browning often occurs around the vascular of potato tubers where high dose gamma irradiation is done soon after harvest for sprout inhibition (Tatsumi *et al.*, 1972, 1973).

It can be concluded that gamma radiation is a very effective technique to prevent sprouting in the *Kufri Jyoti* variety of potato within five months after harvesting. Treating the samples with 100 Gy after 30 days of harvest and storing at 15°C produced very satisfactory result. Radiation with 200 Gy was found to be detrimental for the potato and resulted in unfavourable changes such as skin darkening, black spot, shrivelling occurred in samples. Storage temperature & irradiation date had insignificant effect on firmness. Early irradiation interrupt wound healing and suberization process. Again, the lower temperature storage is generally avoided to prevent cold induced sweetening phenomena. So it is concluded that, to supress the sprouting of *Kufri Jyoti* potato in a storage period of five months, 100 Gy radiation dose after 30 days of harvest is very much effective and 15°C storage temperature is most suitable. This not only inhibits sprouting, but also keeps the other physical properties intact.

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