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Research Article

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Effect of Modified Atmospheric Packaging (MAP) treatment on post-harvest quality of different varieties of kiwifruit (*Actinidia spp.*) under Cool bot storage condition

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Abstract

Kiwifruit is one of the leading agricultural commodities having the tremendous potential of export to the international market. An experiment was carried out during the period of 20th January to 20th June, 2020 to evaluate the efficacy of modified atmosphere packaging (MAP) on quality and physiochemical characteristics in cool bot storage conditions. There were altogether four varieties and twenty-five fruits of each variety were sealed with modified atmosphere packaging films of 25µ with standard 16 perforations stored in cool bot storage (6-7°Cwith 95-97% RH) condition. The Physiological weight loss %, Cumulative Weight loss (%), Total Soluble Solids (°Brix), Titrable Acidity (%), Vitamin C content, Color changes were obtained according to the measurements applied at harvest and during the storage periods. Though the treatment showed a non-significant effect, the maximum physiological weight loss was observed in Abbott (13.6%) and the minimum was in Hayward (9.21%) at 140 days of cool bot storage whereas cumulative weight loss (%) was the maximum in Allison (71.49%) and the minimum in Hayward (41.29%). The Total Soluble solid (TSS°Brix) were increased and Titrable Acidity (%) and vitamin C content (mg/100 gm) were decreased with the advancement of the storage period. The color value (L^*, a^* and b^*) were also analyzed, and the result showed that Modified Atmospheric Packaging has a beneficial effect to retard the ripening process of kiwifruit in cool bot storage. Thus, the research revealed that modified atmosphere packaging (MAP) i.e. 25µ LDPE in a combination of cool bot storage was more effective to extend the marketable shelf life of kiwi fruit without much affecting on quality perspectives.

Keywords: Color value, Cool bot storage, Cumulative physiological weight loss (%), Modified atmosphere Packaging, Vitamin C content

Introduction:

Being Kiwifruit is a climacteric in nature, it can be stored in low temperature for long periods (at 0°C for 4-6 months) and the mean time it can also be significantly softened when it is exposed to even very little amounts of ethylene (Yang and Lim, 2017). The total area under cultivation is 1169 ha, where the productive area is 895 ha with production 2,064 Mt/ha and productivity 2.31 Mt/ha (MOAD, 2019/2020 which is very low productivity though its importance is high.

Mainly, the production time of kiwifruit was during the month of November to January and beyond this period or after the local kiwifruit season ends, huge amount was imported on the local market and the market was flooded with imported fruits and they cost more too . Up to now in our country, there was no post-harvest technology developed besides cold storage So to substitute the international market of kiwifruit the technology of atmospheric packaging was aimed to develop in cool bot storage thus the producers were benefitted by getting higher price in a lean period.

Losses in fruit quality are mostly due to its relatively high metabolic activity during storage So, Cool storage is widely used to reduce respiration rate and extend the shelf life of kiwifruit. The cool bot system is a viable option for small holder farmers who can't afford the expensive conventional cold rooms since it's cheaper. It also saves up to 60% of the electricity bills hence small holder farmers organized in a group can benefit from it (Dubey, 2016).

Moreover, postharvest life and quality of kiwifruit can be extended by some other techniques in combination with cool storage (Fallik, 2004). Salicylic acid (SA), calcium dips, edible coating and modified atmospheric packaging are several choices to reduce moisture losses, restriction of oxygen uptake, reduction in respiration, retardant ethylene production that will be result in retardant of discoloration and will also inhibit microbial growth (Fisk et. al., 2008, Yao and Tian 2005, Montanaro et al. 2006). Water loss (shrivelling) had been identified as the most significant cause of commercial loss in kiwifruit (Hassall et. al., 1998). Some chemical parameters, like soluble solids content (TSS), Titrable acidity (TA), Electrical Conductivity (*EC) Vitamin C content, have also been used to determine fruit quality (Marsh et. Al., 2004, Jha et al., 2007).

Modified atmosphere Packaging (MAP) technology restricts the gas permeability, arranges the amount of oxygen and carbon dioxide in the package, reduces rate, so extending the post-harvest life and maintaining the quality of fruits and vegetables (Ozturk, 2019). Kader, 1989 reported that maintain the natural color in processed and stored fruit has been one of the major challenge to enhance the fruit quality.

Therefore, the objective of the present study is carried out to evaluate the additive benefits of the combination of modified atmospheric packaging (MAP) and cool bot storage condition in kiwifruit.

Materials and Methodology:

Fruits were harvested at commercial maturity stage (TSS 8-10%) from Surya Organic Farm, Patlekhet, Kavre (1400 masl). Fruits were subsequently transferred to National Horticulture Research Center (NHRC) Laboratory at next day after cooling and sorted based on size and the absence of physical injuries or infections. This experiment was conducted during January to June, 2020. The test was performed in completely randomized design (CRD) with five replications in four varieties namely Allison, Bruno, Hayward and Monty. 25 kiwi fruits of each variety were sealed with Modified Atmosphere Packaging films of Low Density Polythene poly films of 25µ with standard 16 perforations and kept on cool bot storage condition having mean temperature of 6-7°C temperature with 97-99% relative humidity. Fruits were measured at the beginning of the experiment just after harvest, and there after every 20 days' interval from 20th January to 20th June, 2020

Physiological Weight Loss (PLW%)

The experimental samples (Twenty-five fruits of each treatment) were weighed at the beginning of the experiment just after harvest and thereafter every 20 days of the interval using a digital balance (SACLTREC SPB42) from 20th January to 20th June, 2020 Fruit weight loss was calculated by using the following formula;

$$\textit{Fruit weight loss (\%)} = \frac{\textit{Initial Weight-Final weight}}{\textit{Initial weight}} \times 100$$

TSS (Total soluble solids0Brix):

The two fruits were squeezed and the juice was extracted from the fruits. The juice was used for TSS determination using Pocket Brix Acidity Meter (model: PAL-BXACID F5 Cat.No. 7100) in °Brix by placing two to three drops of clear juice on the prism surface.

Titrable Acidity (%):

The extracted kiwifruit juice was diluted to 1:50 ratios and TA was recorded using pocket Brix-Acidity Meter (Model:PAL-BX ACID F5 Cat.No.7100) in percentage by placing 1 to 2 drops of diluted juice on the prism surface.

Vitamin C:

The ascorbic acid of kiwifruits was measured by volumetric method as per the reference from Sadasivsm and Manickam (1991). Following formula was used to calculate the ascorbic acid content. Amount of ascorbic acid (mg/100 gm sample)

$$= \frac{0.5\ \text{mg} \times \text{V2ml} \times 12\ \text{ml} \times 100}{\text{V1 ml} \times 5\text{ml} \times \text{wt. of the sample}}$$

Where, V1= amount of dye consumed during the titration

V2= amount of dye consumed when the supernatant was titrated with 4% oxalic acid

Procedure used in the determination of Vitamin C

Five ml of working standard was pipette out into a 100 ml of conical flask. Then 10 ml of 4% oxalic acid was added and titration was done against the dye. This consumed amount of dye (v1 ml) was the amount of V1 in formula. The amount of dye consumed till end point as represented by the appearance of pink coloration was equivalent to the amount of ascorbic acid.

Two ml of sample was extracted in 4% oxalic acid and 12 ml of known volume was made and centrifuged. Five ml of this supernatant were pipette out to which 10 ml of 4% oxalic acid was added and titration was done against the dye. This consumed amount of dye was the amount of V2 in formula.

Color value:

The colour of kiwifruit skin in terms of L*, a*, b* values were determined using a Minolta colorimeter (CR-3000 Model). L* denotes the lightness or darkness; a* is green or red; b is blue or yellow colour of the sample. Measurements were conducted on skin (Jha et al., 2005).

Fruit Freshness (1-5 Scale)

Freshness of the kiwifruit was measured using 1 to 5 hedonic scales. 1 for most freshness or least shrivelled and 5 for least freshness and more shrivelled. The panellist of 10 total scientists was involved in scoring the freshness of the fruit on the last 140 days of storage under cool bot condition. Shelf life is a period of time that started from harvesting and extends up to the start of the rotting of fruits (Mondal, 2000).

Statistical analysis

The data for the experiment was analysed as completely randomized blocks design with four replicates. An analysis of variance was used to analyse difference between means and the LSD test was applied for mean separation at P 0.05. All analyses were done through GenStat 532-2 statistical software.

Result:

Physiological weight loss (PLW %)

Non-significant difference on weight loss was observed on four varieties in the first 20 days of storage and afterwards, they showed significant effect up to 100 days of storage. And then again after 100 days of storage they showed non-significant effect. Though the varieties showed non-significant effect, maximum weight loss was observed in Abbott (13.6%) followed by Bruno (13.1%) whereas percent weight loss was minimum in Hayward (9.2%) (Table 1) However, Cumulative physiological weight loss was maximum observed in Allison (71.49%) and minimum cumulative weight loss (41.29) was observed in Hayward (Fig 1).

Table 1. Effect of modified atmospheric packaging and storage condition on Physiological weight loss (PWL%) in Kiwifruit

Varieties	Wt. loss% (Day 20)	Wt. loss% (Day 40)	Wt. loss% (Day 60)	Wt. loss% (Day 80)	Wt. loss% (Day 100)	Wt. loss% (Day 120)	Wt. Loss% (Day 140)
Bruno	0.830	0.26	4.08	4.08	13.5	8.8	13.1
Allison	0.760	16.75	6.54	6.54	19.0	11.7	10.2
Hayward	0.796	5.62	3.24	3.24	8.4	10.8	9.2
Abbott	0.642	9.08	1.27	1.27	24.8	10.3	13.6
Grand Mean	**0.757**	**7.93**	**3.79**	**3.79**	**16.4**	**10.4**	**11.5**
F-value	**0.892**	**.001**	**.001**	**.001**	**.001**	**0.826**	**0.641**
LSD (0.05)	**0.541**	**5.231**	**5.231**	**2.054**	**7.36**	**6.70**	**8.52**
CV%	**53.4**	**49.2**	**49.2**	**40.5**	**33.4**	**48.0**	**55.1**

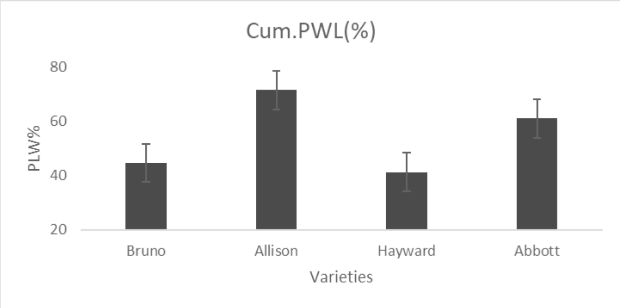

Fig: 1 Cumulative Physiological weight loss (%) of different varieties of kiwifruit under cool bot storage

TSS (Total Soluble Solids °Brix)

During the storage of kiwifruit at cool bot condition the chemical composition changes i.e. Total Soluble Solids (TSS) were highly significant within the five varieties on 100 and 140 days of storage while showed non-significant effect on other days of stage. Though the varieties showed non-significant effect, the low TSS content (8.60 ºBrix) was obtained by variety Bruno and the highest TSS was in variety Abbott (10.72ºBrix) at harvest condition. During 120 days of storage the TSS content was highest in Hayward (13.61) which was only 9.74 at harvest stage and increased up to 14.30 at 140 days of storage followed by Abbott (12.57) which was only 10.72 and increased up to 13.76 and afterwards the fruits texture was on shriveling stage and quality deteriorates (Table 2).

Table 2. Effect of modified atmospheric packaging and storage condition on Total Soluble Solids (TSS°Brix) in Kiwifruit

Varieties	TSSºBrix (At harvest)	TSSºBrix (Day 1)	TSSºBrix (Day 2)	TSS ºBrix (Day 3)	TSSºBrix (Days 4)	TSSºBrix (Day 5)	TSSºBrix (Day 6)	TSS ºBrix (Day 7)
Bruno	8.60	9.28	10.4	11.30	11.70	10.95	11.46	13.40
Alllison	9.44	9.14	10.38	9.42	11.64	9.81	10.47	11.38
Hayward	9.74	11.24	12.10	12.24	13.58	13.61	11.39	14.30
Abbott	10.72	10.57	12.3	11.77	13.48	12.57	12.26	13.76
Grand Mean	**9.62**	**10.06**	**11.21**	**11.18**	**12.60**	**11.73**	**11.40**	**13.21**
F-value	**0.009**	**0.023**	**0.041**	**0.010**	**0.003**	**<.001**	**0.128**	**<.001**
LSD (0.05)	**1.126**	**1.488**	**1.869**	**1.617**	**1.225**	**1.210**	**1.479**	**1.165**
CV%	**8.7**	**11.0**	**12.4**	**10.8**	**7.2**	**7.7**	**9.7**	**6.6**

Titratable Acidity (TA%):

During the storage of kiwifruit at cool bot condition, the TA content of kiwifruit were highly significant upto 40 days of storage. During the harvest, the lowest TA content was observed at Abbott (0.45%) and highest TA (0.66%) was in Bruno and decreased to 0.25% to 0.27% at 140 days of storage respectively though they were insignificant to each-other (Table 3).

Table 3. Effect of modified atmospheric packaging and storage condition on Titrable Acidity (TA%) in Kiwifruit

Varieties	TA% (At harvest)	TA% (Day 20)	TA% (Day 40)	TA% (Day 60)	TA% (Days 80)	TA% (Day 100)	TA% (Day 120)	TA% (Day 140)
Bruno	0.662	0.56	0.52	0.33	0.31	0.29	0.29	0.27
Allison	0.640	0.53	0.44	0.42	0.40	0.37	0.37	0.34
Hayward	0.488	0.45	0.43	0.40	0.38	0.36	0.36	0.35
Abbott	0.458	0.41	0.38	0.32	0.30	0.28	0.28	0.25
Grand Mean	**0.562**	**0.491**	**0.44**	**0.37**	**0.352**	**0.329**	**0.329**	**0.307**
F-value	**<.001**	**<.001**	**<.001**	**0.020**	**0.030**	**0.047**	**0.047**	**0.038**
LSD (0.05)	**0.046**	**0.04**	**0.05**	**0.07**	**0.07**	**0.07**	**0.07**	**0.07**
CV%	**6.0**	**7.1**	**8.3**	**13.9**	**15.0**	**16.8**	**16.8**	**18.1**

Vitamin C content:

Vitamin C content in kiwifruit decreased with the advancement of storage period. During the storage period, Vitamin C showed highly significant within the varieties. The high vitamin C content was observed by Hayward (99.3 mg/100g) followed by Abbott (95.2mg/100g) at 20 days of storage and decreased up to 86.6 mg/100g in Hayward and 90.6 in Abbott at 140 days of storage (Table 4).

Table 4. Effect of modified atmospheric packaging and storage condition on Vitamin C (mg/100g) in Kiwifruit

Varieties	Vit. C content (mg/100g) (Days 20)	Vit. C content (mg/100g) (Day 40)	Vit. C content (mg/100g) (Day 60)	Vit. C Content (mg/100g) (Days 80)	Vit.C Content (mg/100g) (Days 100)	Vit.C Content (mg/100g) (Day 120)	Vit.C Content (mg/100g) (Day 140)
Bruno	73.6	73.8	71.5	67.0	63.7	63.7	63.7
Allison	99.3	99.2	96.9	91.5	86.6	86.6	86.6
Hayward	95.2	101.2	94.2	95.4	90.6	90.6	90.6
Abbott	68.1	69.1	62.1	59.3	57.4	57.4	57.4
Grand Mean	**84.0**	**85.8**	**81.2**	**77.8**	**74.6**	**74.6**	**74.6**
F-value	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**
LSD (0.05)	**7.59**	**7.35**	**6.43**	**7.22**	**6.71**	**6.71**	**6.71**
CV%	**6.7**	**6.4**	**5.9**	**6.9**	**6.7**	**6.7**	**6.7**

Color value

The L* value was highly significant at 60, 80 and 140 days and showed non-significant on other days of storage. The L* value is a measure of the lightness of an object (Lee et al., 2010). The decrease in L* value generally refers to the state of blackening on the surface of fruit (Beirao-da-Costa et al., 2006). Fattahi et al. (2010) reported that the decrease in L* value represents the dark colour due to oxidative browning reaction or the increase in brown pigment concentration. During the experiment, the L* value in fruit skin decreased in cold storage. In previous study, the L* and b* values of skin decreased from 47.41 to 46.88 (1.12% decrease) and 27.63 to 22.08 (20.09% decrease) respectively. The skin colour of kiwifruit Hayward determined as L*, a* and b* value was 43.94, 5.51 and 24.04 respectively (Celik et al., 2007) (Table 5).

Table 5. Effect of modified atmospheric packaging and storage condition on Colour value (L^*, a^* and b^*) in Kiwifruit

	Color Value (L^*)						
Varieties	**(Days 20)**	**(Day 40)**	**(Day 60)**	**(Days 80)**	**(Days 100)**	**(Day 120)**	**(Day 140)**
Bruno	39.32	38.46	35.48	36.84	36.27	40.9	35.86
Allison	39.86	39.65	40.20	38.73	35.27	45.5	38.61
Hayward	40.36	37.99	39.07	40.76	40.07	46.9	37.76
Abbott	39.53	39.51	39.75	40.20	39.00	41.3	38.76
Grand Mean	**39.77**	**38.90**	**38.62**	**39.13**	**37.65**	**43.6**	**37.75**
F-value	**0.626**	**0.350**	**<.001**	**<.001**	**0.035**	**0.130**	**<.001**
LSD (0.05)	**1.757**	**2.23**	**1.424**	**1.367**	**3.528**	**6.10**	**1.268**
CV%	**3.3**	**4.3**	**2.8**	**2.6**	**7.0**	**10.4**	**2.5**

	Color value (a*)						
Varieties	**(Days 20)**	**(Days 40)**	**(Day 60)**	**(Day 80)**	**(Days 100)**	**(Day 120)**	**(Day 140)**
Bruno	9.09	8.60	8.26	8.21	7.46	7.17	7.04
Allison	6.67	7.02	6.72	6.60	7.16	6.47	6.72
Hayward	7.47	7.20	7.15	7.61	7.00	7.40	7.47
Abbott	7.32	7.54	7.27	7.35	6.71	7.56	7.32
Grand Mean	**7.14**	**7.59**	**7.35**	**7.44**	**7.08**	**7.15**	**7.15**
F-value	**<.001**	**0.106**	**0.020**	**<.001**	**0.506**	**0.390**	**0.390**
LSD (0.05)	**0.637**	**1.371**	**0.936**	**0.40**	**1.043**	**1.402**	**1.402**
CV%	**6.3**	**13.5**	**9.5**	**4.1**	**11.0**	**14.6**	**14.6**

	Color Value (b*)						
Varieties	**(Days 20)**	**(Day 40)**	**(Day 60)**	**(Days 80)**	**(Days 100)**	**(Day 120)**	**(Day 140)**
Bruno	20.74	20.38	36.84	21.69	20.75	18.79	20.09
Allison	20.75	20.37	38.73	19.73	19.12	17.46	18.16
Hayward	20.68	21.17	40.76	21.40	20.89	15.86	19.45
Abbott	20.10	19.93	40.20	20.35	21.08	16.88	19.91
Grand Mean	**20.57**	**20.46**	**39.13**	**20.79**	**20.46**	**17.25**	**19.40**
F-value	**0.881**	**0.350**	**<.001**	**0.078**	**0.008**	**0.421**	**0.004**
LSD (0.05)	**1.985**	**1.426**	**1.367**	**1.655**	**1.148**	**3.680**	**1.008**
CV%	**7.2**	**5.2**	**2.6**	**5.9**	**4.2**	**15.9**	**3.9**

Freshness

More freshness and least shriveled was obtained in Allison (1.2) followed by Hayward (2.3) while the least freshness and more shriveling of kiwifruit skin was observed in Bruno (3.4) (Fig:2).

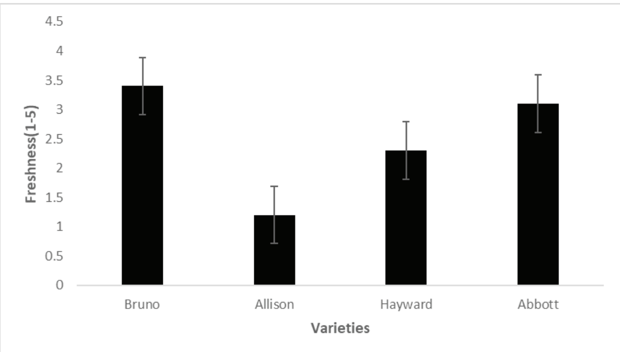

Fig 2: The freshness of different varieties of kiwifruit at 140 days of cool bot storage

Discussion:

In parallel with the results of our study, Fonseca et al. (2002) stated that MAP treatment reduced weight losses in fruit during cold storage. The loss of weight in fresh fruit and vegetable is mainly due to the loss of $H2_O$ caused by transpiration, respiration and VPD between fresh produce and surrounding air. It thought that modified atmosphere packaging decrease in respiration rate and fruit weight losses. Several Studies have shown that modified atmosphere packaging (MAP), and controlled atmosphere storage have the ability to delay quality losses and thus extend shelf life of fresh or minimallyprocessed or fresh-cut produce (Church, 1994; Gil et. al., 1996a). Modified atmosphere packaging of fruits can result in reduction of respiratory activity, delay in softening and ripening and a reduced incidence of various physiological disorders and pathogenic infestations (Artes, 1993).

According to Wills et al., 1998, under controlled treatement condition, the TSS content of fruits were rapidly increased due to faster loss of water, utilization of starch, polysaccharides as energy and conversion into soluble sugar and decrease of titrable acidity is due to consumption as energy source for respiration and other physiological processes after harvest . And the meantime, Reddy et al 2008 observed that LDPE packaging as an effective material to minimize the increase in TSS content. In contrast, total titrable acidity (TTA) in all fruits decreased gradually as ripening progressed irrespective of the storage conditions or packaging. In most climacteric fruits acidity declines as ripening advances (Wills et al., 1989). The increase in TSS content is due to the hydrolytic change in starch and conversion of starch to sugar, which is an important index of the ripening process in fruits (Arthey and Ashurst 2005). Increased Sucrose Phosphate Synthase enzyme activity causes an increase in TSS during kiwi maturation which converts starch into simple sugars such as glucose phosphate. This enzyme is activated by ethylene hormones during the maturation process (Boquete et al., 2004).

Kiwifruit is small caloric and has high amounts of vitamin C which is higher than that determined in orange, strawberry, lemon and grapefruits. This finding was correlated with Tavarini et al (2008) who reported that vitamin C concentration in fruits of CV. Hayward decreased at the end of the long cool storage (6 months). The vitamin C decrease was attributed to the oxidation of ascorbic acid into dihedron-ascorbic acid by the enzyme ascorbic acid oxidase (Jany et al., 2008). These study supports the findings of the present study.

The color of the fruits and vegetables is controlled by natural pigments in their structure, and changes may occur with the maturation period (Barrett et al., 2010). In addition, the colour formation has seen as a quality indicator in foods (Hutchings et al., 2012), and it affects consumer preference in many fruit types. Generally, in the study, it was seen that MAP treatments had a retarding effect on color development in kiwifruit. Aglar et al., 2017, reported that MAP treatment retarded the color development in storage and shelf life period in sweet cherry, and Ali et al., (2019) reported that MAP treatments delayed enzymatic browning at litchi fruit. In previous studies, cold storage has been coupled with waxing and MAP to extend the shelf life of Avocado (Mendeta et al., 2016) and Mango fruit (Kelany et al., 2010) respectively.

Conclusion and Recommendation:

The above experiment concluded that Modified Atmospheric Packaging (MAP) i.e. 25μ LDPE with 16 perforations was found effective in kiwifruit stored cool bot conditions. It was observed that Cumulative Physiological weight loss was minimum in Hayward (41.29 %) and the highest loss (71.49%) observed in Allison. Similarly, Total Soluble Solids were progressively increased and Titrable Acidity and Vitamin C content were decreased with the advancement of storage period. The Cool bot storage technology has been found to be effective in extending shelf life and preserving the quality of kiwifruits and it extends the marketable shelf life up to 140 days. It is recommended for adoption by smallholder farmers so as to reduce the high post-harvest losses. Farmers will also be able to store their produce longer after harvest when there is a market glut and sell when the prices go up hence increasing their profit margin. It was recommended that research should be done on other perishable commodities and their response to Cool bot storage documented for wider use of the technology.

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Declaration of conflict of interest and ethical approval:

M. Dhakal involved in designing, conducting experiment, analyzing and interpreting the results and preparing manuscript. I.P. Gautam involved in supervising the experimental work, providing guidelines for result interpretation and manuscript preparation. D. Ghimire, and S. Poudel, involved in conducting lab experiment and manuscript preparation and S.Pandey involved in data analysis and manuscript preparation. The authors declare no conflicts of interest regarding publication of this manuscript.

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