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Mechanical Properties of Spinach

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Abstract: *In this paper, the mechanical properties such as brust strength, toughness, displacement were determined for spinach of the local variety. These properties are necessary in the processing and transportation, separating and packing. The results showed that on six different packaging materials, namely plastic punnet, bamboo basket, plastic net bag, LDPE bag, polyethylene bag, LDPE wrapping, Mechanical properties was increased with the increasing in spinach storage time. Maximum burst strength (3.815 N) and displacement (5.280 mm) were found, in spinach packed in bamboo basket and toughness (6.704 N.sec) was found to be maximum in spinach packed in plastic net bag in ambient storage, while in cold storage Maximum burst strength (4.354 N) and displacement (5.096 mm) were found, in spinach packed in LDPE bag and toughness (11.366 N.sec) was found to be maximum in spinach packed in plastic punnet.*

I. Introduction

Vegetables play an important role in meeting the needs of human beings for vitamins and minerals. Spinach (*Beta vulgaris* L.) is an important leafy vegetable commonly grown in India. It contains 91.4% moisture, 2.2% fibre, 3.6% carbohydrate, 0.4% fat and rich source of vitamin A, iron and calcium (Anonymous, 2009).

Mechanical properties are needed for texture analysis and better understanding product quality. Texture perception and texture acceptability are critical factors in quality evaluation of fruit and vegetable products offered on market (Nabil, *et. al.* 2012). The peak force was the burst strength and the displacement was the distance to burst, which is an indication of the flexibility of the spinach leaf. Toughness was measured as the area under the force-displacement curve (Anonymous, 2013).

Work has been conducted on the study of mechanical properties of spinach. However, sufficient information about vegetable like spinach appears to be lacking. This information will be useful in identifying the most shelf-stable product of spinach and appropriate packaging materials.

II. Materilas And Methods

The research was carried out at the department of Agricultural Process Engineering, college of agricultural engineering and technology, VNMKV, Parbhani during 2013-14.

Sample Preparation

Fresh spinach (*Beta vulgaris,* L.) (Var. local) were procured after harvesting in the morning hours from commercial plantation located near the Parbhani city. Fresh, uniform size and matured spinach (Var. local) were procured from local farmer, Parbhani. Sorting and grading were done manually to remove diseased and non uniform spinach leaves. Clean leaves were taken for experiment.

Experimental layout and design The design of experiment was carried out by the software: DESIGN EXPERT Version 8.0.7.1, Full Factorial Design with six responses of packaging materials and two categories of storage conditions.

Independent variables		**Treatments**	**Dependent variables**
Packaging system	**Storage**		
Different packaging systems for spinach	Ambient (S_1)	S_1P_1, S_1P_2, S_1P_3, S_1P_4, S_1P_5, S_1P_6.	Mechanical properties. (Brust strength, Toughness, Displacement)
	Cold (S_2)	S_2P_1, S_2P_2, S_2P_3, S_2 P_4, S_2P_5, S_2P_6.	

Where,
S_1:Spinach leaves stored at ambient condition. S_2:Spinach leaves stored at cold condition.
P_1 :Spinach leaves packed in plastic punnet.
P_2:Spinach leaves packed in bamboo basket.
P_3: Spinach leaves packed in plastic net bag.
P_4:Spinach leaves packed in LDPE bag.

P_5:Spinach leaves packed in polyethylene bag.
P_6 :Spinach leaves packed in LDPE wrapping.

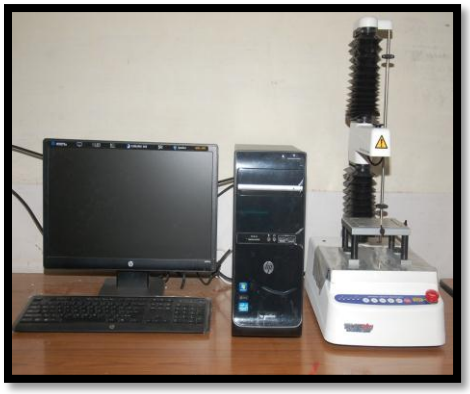
Storage conditions

1. Ambient storage (Room temperature) (S_1): The spinach packed in different packaging materials and kept in the Agricultural Process Engineering laboratory for storage. The average temperature and relative humidity were ranged 22.2 ^oC to 38.3 ^oC and RH 55 % to 65 % respectively.

2. Cold storage (S_2):

Cold storage was used to store the spinach for predetermined temperature at 4 ºC and 90% relative humidity for storage period of fourteen days (Piagentini, 2002).

Mechanical properties: For measuring the textural quality of spinach, the TA-XT plus texture analyzer was used. Leaves were analyzed using the punch test to assess the leaf fracture properties. This procedure involves forcing a probe of known cross-sectional area through a section of a leaf (Eduardo *et al.* 2012). The punch test was conducted at room temperature using the texture analyzer TA-XT plus from Stable Microsystems (Godalming, UK).



Texture analyzer

The 5 mm stainless steel spherical probe (P/5S) and Perspex film support platform with Aluminum circular top plate used in Texture analyzer.

The test involved using a 5 mm spherical ball probe to penetrate the leaf at a pre-test speed of 2 mm s^{-1}, a test speed of 1 mm s^{-1} as the probe contacted the leaf and a post-test speed of 10 mm s^{-1}. Each leaf was placed between two clamped metal plates with coinciding holes (area of 0.785m^2) to keep the leaf flat. The probe moved a standard distance of 10 mm. The clearance between the probe and the hole in the plates was 50 mm. From this test a force–displacement graph for each randomly selected spinach leaf was generated and the fracture properties (1) Burst strength, (2) Toughness and (3) The displacement of the probe necessary to fracture each leaf were recorded. The peak force is the burst strength and the displacement is the distance to burst, which is an indication of the flexibility of the spinach leaf. Toughness was measured as the area under the force–displacement curve (Anonymous, 2013e).

Table 1.Texture application details

TA Settings		
Mode	:	Measure force in compression
Option	:	Return to start
Pre-test speed	:	2.0 mm/s
Test speed	:	1.0 mm/s
Post-test speed	:	10.0 mm/s
Target mode	:	Distance

Distance	:	10 mm
Trigger type	:	Auto 0.0490N
Tare mode	:	Auto
Data acquisition rate	:	500 pps.

Data collection and analysis:
The experimental design was carried out by the software: DESIGN EXPERT Version 8.0.7.1. Full factorial design (mode: 2FI i.e. two factorial) was used with six levels of packaging materials of each variables.

III. Results And Discussion

During the investigation of mechanical properties of spinach, the variation in burst strength, toughness and displacements were observed and showed in Table. From DESIGN EXPERT ANOVA test, it was observed that effect of packaging materials on mechanical properties of spinach stored at ambient condition was found statistically significant at 5% level of significance. Also the interaction effect between packaging materials P and storage days D, i.e. (P x D) was found significant at 5% level of significance. 0 day sample (Fresh) preferred as a control sample.

Effect of packaging materials on mechanical properties of spinach stored at ambient condition (S_1).

The burst strength, toughness and displacements varied between 1.134N to 3.815N; 1.690N.sec to 6.704N.sec and 2.341mm to 5.280mm respectively during storage period. From the Fig.1-3, it is indicated that burst strength was maximum burst strength and displacement were found, in treatment P_2: spinach packed in bamboo basket and toughness was found to be maximum in treatment P_3: spinach packed in plastic net bag. Stored sample in all packaging material spoiled on 4th day of storage period. From Fig.1-3, result, showed that the burst strength, toughness and displacement increased with increase in storage time. For spinach samples, greater forces were necessary to penetrate the leaves. Due to increase in puncture forces mechanical properties shows greater values during storage period for better packaging (Nabil, 2012). According to mechanical properties bamboo basket was found to be better packaging material in respect with burst strength and displacement while plastic net bag found to be better packaging material in respect with toughness during the storage

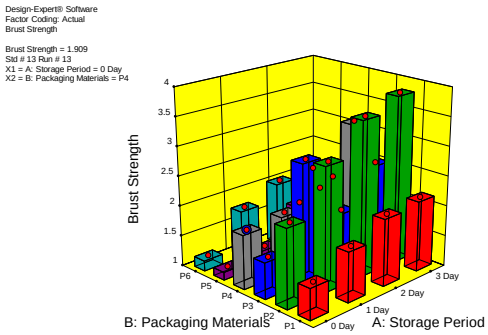


Fig.1: Effect of packaging materials on brust strength of spinach stored at ambient condition.

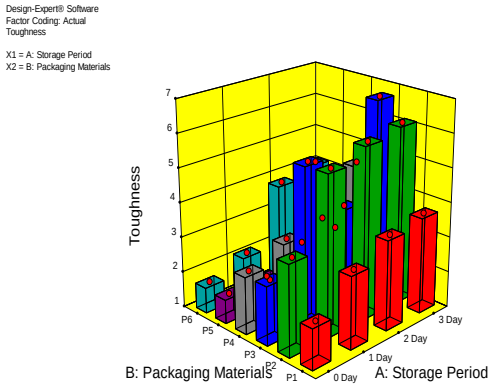


Fig.2: Effect of packaging materials on toughness of spinach stored at ambient condition.

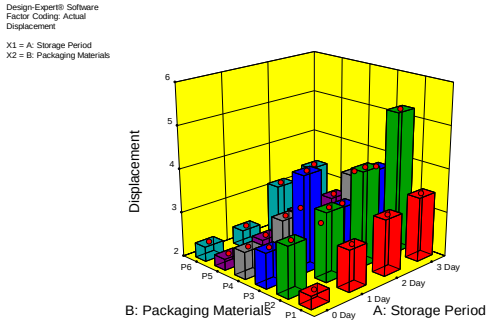


Fig.3: Effect of packaging materials on displacement of spinach stored at ambient condition.

Effect of packaging materials on mechanical properties of spinach stored at cold condition (S_2).

The burst strength, toughness and displacements varied between 1.075N to 4.354N; 1.860N.sec to 11.366N.sec and 1.722mm to 5.096mm respectively during storage period. From the Fig.4-6, it is indicated that burst strength and displacement were minimum in treatment P_5: spinach packed in polyethylene bag followed by treatment P_1: spinach packed plastic punnet, while toughness was minimum in treatment P_5: spinach packed in polyethylene bag followed by treatment P_4: spinach packed in LDPE bag. Maximum burst strength and displacement were found, in treatment P_4 : spinach packed in LDPE bag and toughness was found to be maximum in treatment P_1: spinach packed in plastic punnet. For spinach samples, greater forces were necessary to penetrate the leaves. Due to increase in puncture forces mechanical properties shows greater values during storage period for better packaging (Nabil, 2012). According to mechanical properties LDPE bag was found to be better packaging material in respect with burst strength and displacement while plastic punnet found to be better packaging material in respect with toughness during the storage period of 14 days. Fig.4-6, showed that in treatments P_2 and P_3, sample spoiled on the 7^{th} day of storage period while in treatment P_6 sample spoiled on the 10^{th} day of storage period, and all other treatments sample spoiled after the 14^{th} day of storage period.

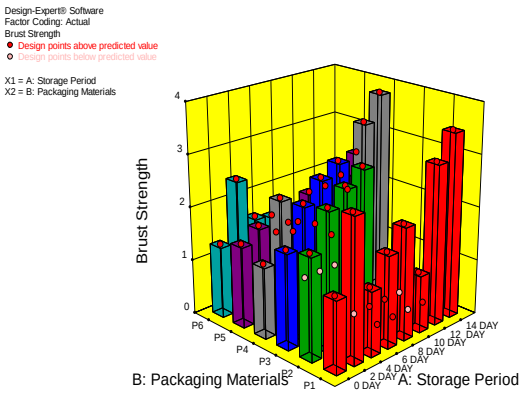


Fig.4: Effect of packaging materials on brust strength of spinach stored at cold condition.

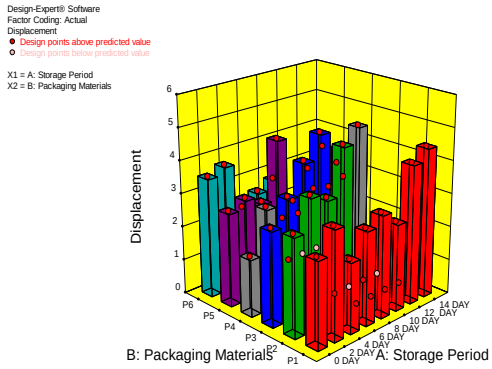


Fig.5: Effect of packaging materials on toughness of spinach stored at cold condition.

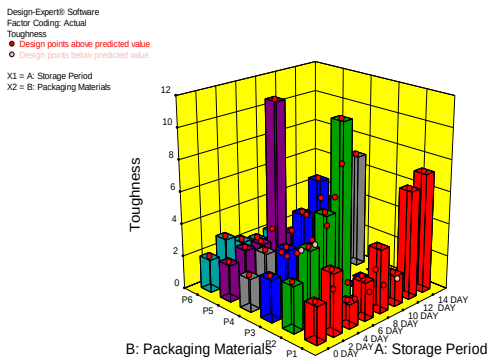


Fig.6: Effect of packaging materials on displacement of spinach stored at cold condition.

IV. Conclusions

Mechanical properties of spinach in bamboo basket was found to be better packaging material in respect with burst strength and displacement while plastic net bag found to be better packaging material in respect with toughness during the ambient storage period of 3 days. Also during cold storage LDPE bag was found to be better packaging material in respect with burst strength and displacement while plastic punnet found to be better packaging material in respect with toughness during the storage period of 14 days.

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