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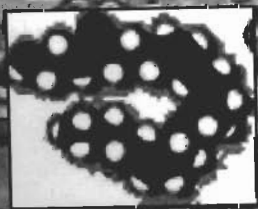

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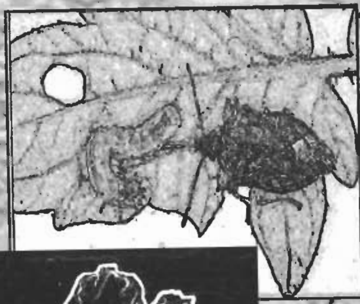

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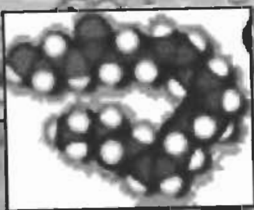

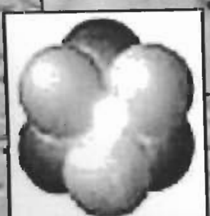

STRESS DISTRIBUTION IN WATERMELON (*CV. 'CRIMSON SWEET'*) UNDER AXIAL COMPRESSION

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INTRODUCTION

Watermelons are mostly loaded in bulk shipments. Bulk loading and storage requires protection of watermelons from load shifting injury (Boyhan, Darbie, Granberry, & Kelley, 2000). To avoid mechanical damage, the magnitude of the applied stress is required to be less than the minimum stresses, which cause internal bruise in watermelon. It is extremely difficult to measure internal stresses caused by the applied compressive forces. An alternative approach is to estimate the stresses using finite element analysis (FEA). With the finite element method (FEM), objects of irregular shapes and non-homogeneous material properties (e.g. modulus of elasticity) can be modeled. FEA has the potential to solve nonlinear problems such as those involving contact and large deformations.

MATERIALS AND METHODS

The major, intermediate and minor diameters of Crimson sweet watermelon were used for the models of the watermelon compression (Table 1). The model geometry was developed using that the "Spline" option of curves. These curves were found to be the most suitable and adapted to watermelon shape geometry that can be defined through the spherical coefficient, area and cross diameters (Sadrnia ,Rajabipour, Jafari, Javadi, & Mostofi, 2007). The variation of the rind thickness was considered in the models.

Table 1. Some physical properties of Crimson sweet watermelon

Parameter	Rind thickness			Dimensions			Spherical coefficient	Mass (Kg)	Volume (cm^3)
	Stem (mm)	Intermediate (mm)	Blossom (cm)	a (cm)	b (cm)	c (cm)			
Mean	2.2	1.4	0.7	24.0	21.1	20.1	0.91	5.3	5629
SD	0.4	0.21	0.13	1.25	0.91	0.92	0.038	0.49	558
CV %	18.2	15	18.6	5.2	4.3	4.6	4.2	9.3	9.9

Two models were developed for watermelon compression. One, was an axisymmetric (2-D) model while the other was a three-dimensional (3-D) model. For the axisymmetric model, only half of the longitudinal cross-section of the watermelon was modeled. The major axis was oriented in the vertical direction. A section of the model is shown in Fig. 1. When the cross-section is rotated 360° around the y-axis

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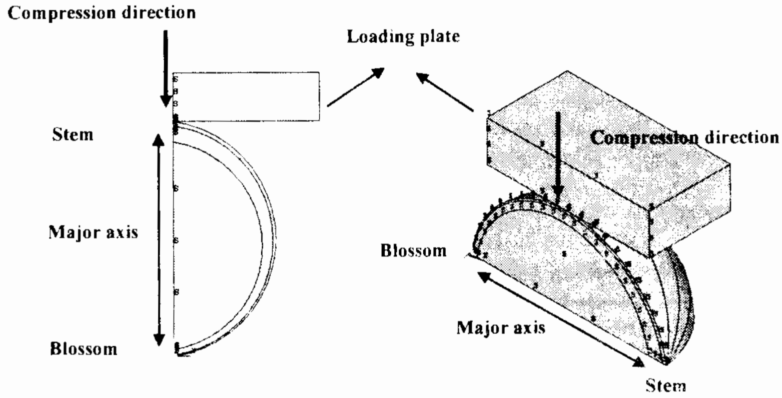
(noted with s in Fig. 1-a) it is a whole watermelon approximately. This model is proper for analysis of the forces applied by the plate in the longitudinal axis direction of the fruit (blossom-stem).



(a) (b)

Figure 1. Geometric models for compression in (a) the longitudinal direction as 2D model and (b) the transverse direction as 3D model.

The watermelon structure is not axisymmetric in the transverse directions for compression tests, because of rind thickness variation, around applied force axis. Therefore a 3-D model was also developed. The geometry of the 3-D model was determined using all planes of symmetry. This gives two planes of symmetric (noted with s in Fig. 1-b). Cutting the watermelon along these two planes gives a quarter of a watermelon as shown in Fig. 1-b. Both models describe the "thick shell" created geometry without the seed cavity which can contain the non-homogeneous materials. Three different moduli of elasticity were used for the green rind, white rind and red watermelon flesh (Table 2).

Table 2. Failure stress, failure strain, and modulus of elasticity for flesh and rind of "Crimson sweet" and "Charleston gray".

Location	No. Samples	Failure Stress (MPa)	Failure Strain (mm/mm)	Modulus of Elasticity (MPa)
Red flesh	20	0.037	0.095	0.396
White rind	20	0.262	0.219	1.202
Green rind	20	1.144	0.215	5.357

The finite element types considered in the models are as follows. PLANE42 is used for 2-D modeling. The element can be used either as a plane element (plane stress or plane strain) or as an axisymmetric element. The element is defined by four nodes having two degrees of freedom at each node: translations in the nodal x and y directions. The element has large deflection, and large strain capabilities. For the 3-D models, the structural element SOLID45 was used for rind and flesh. The element is defined by eight nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions. Furthermore CONTACT48 and CAN-

TACT49 were used to repr
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RESULTS

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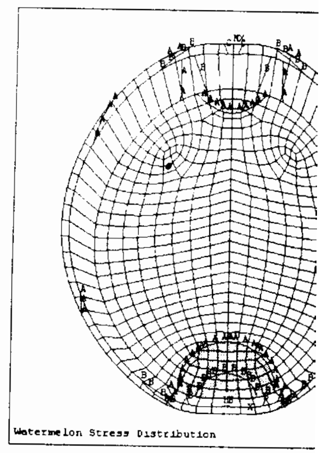

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Figure 2. Equivalent stresses of
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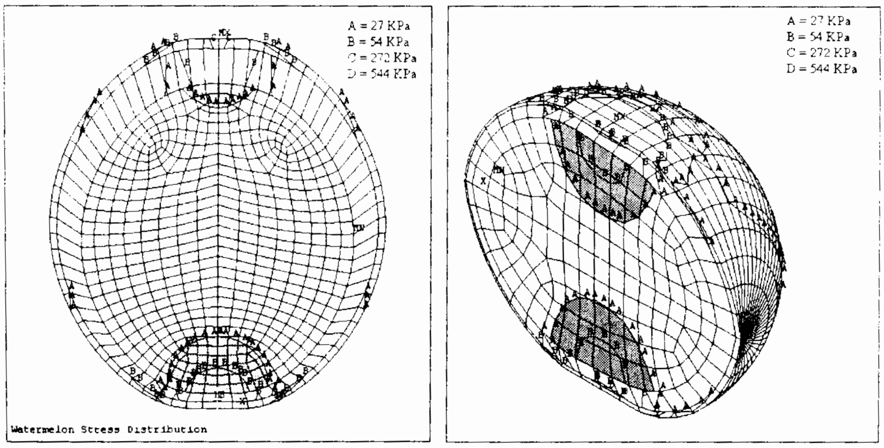
TACT49 were used to represent contact surfaces (fruit surface and compression plates) in 2-D and 3-D models respectively. Those elements are located on the surfaces of objects (ANSYS Help System, 2004).

RESULTS

The stress distribution within the different parts of the watermelon was computed using the nonlinear FEA. The applied loads were much less than breaking force. The compression in longitudinal direction was modeled using the axisymmetric ANSYS model by plane loading. The y-axis of the axisymmetric model was taken as parallel to the direction of the applied forces. The applied force was assumed to be 10 percent of breaking force or 152N for Crimson sweet in the longitudinal direction. The equivalent stresses for the above are shown in Fig. 2. Stress contours are also indicated with similar letters A, B, C and D. The maximum stress (349Kpa) spread in the rind surface and exactly below of upper compression plate. At this value, the rind of watermelons would be intact because of mean failure stress of the rind are much higher than the maximum stress (Table 2). Meanwhile, the minimum equivalent stress is 3.1KPa and located in the red flesh at the equatorial plane. The mean failure stress for the red flesh watermelon tissue is 37KPa. Therefore, probably bruising can occur in red flesh of watermelons in the inner area of the model that has equivalent stress counter signed with "A" letter. As shown in Fig. 2-a, predicted internal bruising is indicated by grey color. By comparison, it appears that the bruising area next to the blossom of watermelon is larger than the bruising area next to stem. This is caused by the difference in rind thickness.



a) b)

Figure 2. Equivalent stresses of the watermelon model compression a) in longitudinal direction b)in transverse direction

The watermelon compression in the transverse direction is modeled using the 3-D ANSYS models. Like for the longitudinal compression, the applied force was set as 10 percent of the breaking force of watermelon in longitudinal direction. The equivalent stress is shown in Fig. 2-b. The maximum stress extended in the rind surface and exactly below the upper compression plate. This value (239Kpa), in comparison with the maximum stress in the longitudinal compression, indicates that the maximum stress in longitudinal compression of watermelon is much higher than maximum stress in the transverse compression. Although, the applied load in transverse compression model is more than longitudinal compression model. Therefore, the model shows that rind breakage occurring in longitudinal compression of watermelon is more probable than transverse compression. The result agrees with experiments of the watermelons compression result in case of breaking force. The minimum equivalent stress is approximately 3.1KPa and located in red flesh on the equatorial plane. This stress is less than those indicated in 2-D model. Grey colored areas in Fig. 2-b show the region of equivalent stresses, which are equal or more than the failure stress of the red tissue. Therefore, it is predicted that bruising would be occurred in these areas.

CONCLUSION

Two finite element models, an axisymmetric and a 3-D model, were applied in ANSYS to analyze the compression of watermelon (Crimson sweet) in longitudinal and transverse directions. According to the results, the axisymmetric model is suitable for symmetrical loading with two plates at two sides of whole watermelon in longitudinal. The 3-D model can be used when the watermelon is loaded with two plates in transverse direction.

The predicted equivalent stresses for all models with applied force, 10 percent of break force measurement, are less than the failure stress of rind. But, the predictions of stresses in the red flesh are higher than the failure stress. Hence, bruise would occur in the area where stresses are equal or more than failure stress of red flesh. Finally, an investigation of maximum stresses in the models shows that breaking force in the longitudinal compression is less than the breaking force in transverse compression. This is in agreement with experiments results.

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USE OF PESTICI
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CONTA

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INTRODUCTION

Point sources of pesticide pc
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In our study, the phenyl ur
Bioaugmentation experiment
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shown to contain a linuron-m
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compare bioaugmentation wi
non-primed soil. As on-site
containing aqueous solution
which did not receive linuro
capacity in the different syst
tion, we examined the effec
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MATERIALS AND METHODS

Experimental set-up

The experiments were perforn
with a mixture of cutted stra
of a glass filter, present at th
ter (with or without 60 mg/l
matrix with a pipet. A glass di