NEURAL BRUISE PREDICTION MODELS FOR FRUIT HANDLING AND MACHINERY EVALUATION

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Abstract: Some neural bruise prediction models have been implemented in the laboratory, for the most traded fruit species and varieties, allowing the prediction of the acceptability or rejectability for damages, with respect to the EC Standards. Different models have been built for both quasi-static (compression) and dynamic (impact) loads covering the whole commercial ripening period of fruits.
A simulation process has been developed gathering the information on laboratory bruise models and load sensor calibrations for different electronic devices (IS-100 and DEA-1, for impact and compression loads respectively).
Some evaluation methodology has been designed gathering the information on the mechanical properties of fruits and the loading records of electronic devices. The evaluation system allows to determine the current stage of fruit handling process and machinery.

Keywords: Load sensors, network models, bruise simulation, decision support system.

1. INTRODUCTION

The current stage of fresh fruit retail market has been worsening. Fresh fruit consumption may decrease due to the lack of quality in the markets. Recent research results (Kamp and Pedersen, 1990) have shown that less than a 10% of the fruits titled Class I followed the EC Standards mainly due to the presence of mechanical damages.

Fruit handling processes and mechanical equipment get more and more complex. The need for an evaluation standarization is clear, in order to objectively compare differences between the machineries. Within this aim the electronic products have been developed (Halderson and Skrobacki, 1986; Brown et al., 1990). However, mechanical properties of fruits have also a great effect on the mechanical damage susceptibility of fruits (Chen and Zongnan, 1981; Chen et al., 1987; García and Ruiz, 1988; Rodriguez et al., 1990; Ruiz Altisent, 1990). So gathering the information on the mechanical properties of fruits is also needed for the evaluation of processes and machinery.

Until now some comparisons between the electronic devices measurements and the mechanical properties of fruits have been made (Brown et al., 1989; Schulte et al., 1992 & 1993; Sober et al., 1990). Day by day a wider range of fruit varieties and storage treatments are used through the same machinery, therefore a wider link between the electronic devices and the mechanical properties of fruit is needed.

Mechanical properties of fruits have been studied

(Barreiro and Ruiz, 1993) and a statistical approach to bruise modelization has been used in order to build up the bruise prediction models and evaluation methodology. Neural network process (Robert et al., 1989; Ros et al., 1993; Steinmetz and Delwiche, 1993) leads to consider whether this type of models would be adapted to bruise modelization or not.

Within this context, the objectives for the current study were:

1) to search for the optimal bruise prediction models,

2) to gather the needed information on the mechanical properties of fruits and the electronic products to simulate bruise appearance, and

3) to design an evaluation methodology for determining the current stage of fruit handling process and machinery with respect to the EC legislation.

2. MATERIAL AND METHODS

All the data employed for the current study were the consequence of a two seasons' work (Barreiro and Ruiz, 1993) where an exhaustive research on fruit mechanical properties and bruise susceptibility was carried out. Both the most common cold storage treatments and load types (compression and impact) were studied; the most exported pome and stone species: apple, pear, peach and apricot were tested. A trading study was made to select the most important varieties:

- apple: "Golden Delicious"
- pear: "Conference" and "Doyenne du Comice"
- peach: "Maycrest" and "Springtime"
- apricot: "Búlida" and "Canino"

2.1. Selection of variables for bruise modelization

The first step for developing the bruise prediction models was to select the variable which would best represent bruise damage. The EC Legislation gives the maximum surface damage allowable for each quality class: 1 cm^2 and 0.5 cm^2 for pome and stone fruits respectively. However, the external surface damage depends on the size of the contact surface between two bodies' during loading, also a function of both bodies' curvature radius (Horsfield et al., 1972). On the other hand, the smaller the curvature radius, the deeper the bruise is. Due to all these facts it was possible to find bruises having an equivalent bruise volume but different bruised external surface, which would consequently have different quality evaluation. Therefore, a new parameter, "bruise section", was created to include these effects. Th way, the units for the bruised section is the same : for the bruised external surface (mm^2).

$$b.s. = \pi \frac{w}{2} d\,(mm^2) \qquad (1)$$

Bruise section is defined in Eq. 1, where w is brui width (mm) and d is bruise depth (mm); it represer twice the internal bruised section area.

As for the selection of the explicative variables (* it was decided to apply the parsimony principle the machinery and on the data to be employed, that the process and the machinery evaluation cou be carried out easily. On the basis of previo studies, (Chen et al., 1987; Rodriguez et al., 19 Ruiz Altisent, 1990; Barreiro and Ruiz, 1993) it w decided to perform a different bruise model for ea variety and loading type (compression or impac including in all of them as explicative variables t following magnitudes: fruit firmness (FR, 1), loadi level (HI for impact or FZC for compression, 2) a storage treatment (ST, 3).

Measuring fruit firmness. The Magness-Tay penetration test is the most common test used i fruit firmness assessment. This testing procedure l two main handicaps: it is a destructive test (so it c only be carried out on samples of fruits), and variation coefficient is high, especially for st fruits. Therefore, through the latest years a n testing machine for fruit firmness sensing has b developed (Chen and Zongnan, 1981; García a Ruiz, 1988; Ruiz Altisent, 1990; Jarén et al., 19 Correa et al., 1992). This device uses low ene impacts for firmness sensing. It allows to measur great number of variables related to the decelerat suffered by the impactor, including the imp duration. Previous research results (Barreiro Ruiz, 1994; Steinmetz et al., 1995) have shown clear relationship between the ratio of maxin impact force over maximum impact deforma (FDR) with the maximum force of the Magn Taylor penetration test.

The impact tester has the advantage of being n more repetitive (usually 10% of coefficient variation aproximately), than Magness-Taylor w may surpass 30% for stone fruits (Barreiro and R 1992). It can also be performed non-destructively a low drop height (Chen and Ruiz, 1994). Fo these reasons the selected variable for firmness the FDR in impact.

* explicative variables are all correlatively numbered.

Loading level variable. Research results carried out previously (Barreiro and Ruiz, 1993) included laboratory and field studies. During the laboratory testing different loading levels were applied for each variety, cold treatment and loading type (compression or impact) in order to achieve bruise damages below and above the EC Standards limits. For impact testing a constant mass was dropped upon the fruits and the impact loading level was measured as a function of the impacter mass dropping height. The compression loading level was fixed as a maximum compression force. The loading levels were included for each compression and impact bruise prediction model in this same way; the relationship between these laboratory load parameters and the electronic devices is shown in Paragraph 4. The electronic devices used during the current research have been an IS-100 (Halderson et al., 1986) measuring impact loads, and a DEA-1 measuring compression loads (Various authors, 1995).

Cold storage variable. Three storage treatment modalities were employed: no cold storage, cold storage with 80% of R.H. and with plastic covering; 1 °C for pome fruits and 4°C for stone fruits. As cold storage had shown its influence on bruise susceptibility, it was decided to include this variable as a discrete parameter and to test afterwards whether it was significant or not for each bruise prediction model.

For the stone fruits, the 80% R.H. cold storage data were not used for bruise modelization, as the treatment showed to be non-commercial: more than 20% of fruit weight losses were produced.

Remarks on apricot models. Apricot varieties present a great variation in their mechanical properties during the harvesting season. This fact is due not only to their biological properties but also to the commercial competition made by the earliest varieties of peaches. This market demand determines the presence of immature fruits in the stores.

Non-mature apricots show great differences in their mechanical properties when compared to mature fruits. A new discrete variable, named "maturity" (M, 4), with two modalities was created. Both non-mature and mature fruits coming out of three different harvesting dates were tested.

A "minimal distance classifier" (Judez, 1989) based on normalized data was used for the maturity assessment of apricots. Inputs to the classifier were all the variables described in previous paragraphs of section 2.

2.2. *Models evaluation methodology*

As a first step, an analysis of variance (ANOVA) at 5% level was carried out to check whether the selected variables were significant for bruise prediction. Afterwards, different neural approaches for bruise prediction were carried out.

The bruise prediction models were compared using the correlation coefficient between bruise prediction and observation. Another way for evaluating bruise prediction models, was the classification under the EC Standards. An error below the EC tolerance (10% for I Class) was used also as a criterion for model acceptation.

Comparison between fruit classification under the EC Standards for predicted and observed damage is presented in Fig. 1, where

A is the percentage of unclassified fruits,
B is the percentage of fruits well classified,
C is the percentage of non detected damage, and
D is the percentage of overdetected damage; both "C" and "D" should be below 10% for the model to be acceptable.

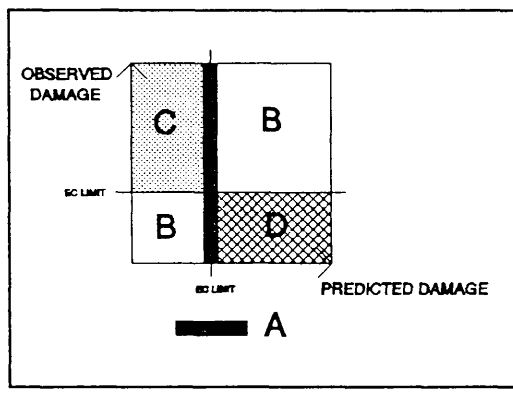

Figure 1. Comparison between fruit classification for predicted and observed damages.

Each group was defined using the whole confidence interval for each prediction (5% of significance level). One prediction had to show the same classification as the observed damage for the whole confidence interval to be considered well classified. The percentage of well classified increased with decreasing confidence interval, that is, increasing model adjustment.
Whenever the confidence interval was between acceptable or rejectable (below and above the EC limit) the fruit was considered unclassified, except if the observed damage was inside the band 5% plus or minus the EC limit. In this case the fruit would be considered well classified, as the observed damage would also be inside the threshold band.

2.3. Neural network approach

Neural networks are based on the emulation of human brain. A net is built with many neurons or processing elements (PE) which are connected. Normally, the neurons inside the brain are connected in a hierarchic way, as it makes the information easier to be gathered. On this basis the feedforward neural networks have been created (Schalkoff, 1992).

The PEs placed at the begining of the network (inputs) were the explicative variables and the PE placed at the end (output) was the bruise section. There was a PE called BIAS equivalent to the offset in the statistical procedures.

The transformation function (Eq. 2) can be selected depending on the characteristics of the inputs and the outputs. For bruise prediction, a sigmoid function was selected. This function was obtained initially from a biological model and allows to find non linear relationships.

$$f(x) = \frac{1}{1+e^{-\lambda x}} \qquad (2)$$

The number of iteractions (weight corrections) was fixed empyrically in 40.000 for pome fruits and 20.000 for stone fruits. These numbers correspond to the number of iteractions required until the convergence of the learning process is achieved. There were about 30% more individuals for the pome than for the stone varieties.

For neural approaches, a training as well as a testing set were used. The testing set contained about half the number of samples of the training set; this testing set was made out of the second repetition of the 1993 season's tests. The testing set was not included for the models adjustment, allowing to determine the models robustness by comparing the coefficient of determination for the training and the testing sets. The evaluation of the samples classification under the EC Standards was used only for the training set as a low number of samples may lead to a biased result.

Whenever it was not possible to achieve a better "generalist" solution, that is using all data for each model, for neural network approaches it was decided to check whether a sample selection or a "specialist" net training could give better results or not. Two approaches were studied:

1) the first one was <u>sample selection</u>. As the training set contained a large number of individuals, the presence of high number of individuals of certain characteristics could determine an overtraining learning for the generalist network. Therefore, a training sample was created following the Warc aggregation criterion (Judez et al., 1989). An inerti: threshold was chosen bellow which every group o individuals would be selected. The net training wa carried out on this selected sample and afterward retrained for the whole sample; the learnin coefficients for the second approach were lower, t avoid oscillation.

2) the second one was <u>specialist network</u>. For thi solution, it was necessary to find out the areas wher learning was low and to build a network coverin that range of data. Once the area had been chosen, "minimal distance classifier" was used to know und which network unknown individuals should be teste

3. RESULTS FOR BRUISE PREDICTION MODELS

3.1. Results for the initial neural approaches

Neural approaches were carried out using t Neuralworks Professional II plus software. The fi net architecture is shown in Table 1. Each net identified by three digits corresponding to the numb of inputs, PEs in the hidden layer and outputs.

<u>Table 1. First neural architecture.</u>

	Model	
Variety	Compression	Impact
"Conference"	3-1-1	3-1-1
"Doyenne"	3-1-1	3-0-1
"Golden"	3-1-1	3-1-1
"Maycrest"	3-1-1	3-1-1
"Springtime"	3-1-1	3-1-1
"Búlida"	4-1-1	4-1-1
"Canino"	4-1-1	4-1-1

The results obtained with neural processing did achieve the desired error range ("C" and "D" be 10%, see Fig. 1) in most cases; even increasing number of hidden PEs did not improve the ov results. Therefore, it was decided to check wheth sample selection or a "specialist" network could l to better results, as it has been explained in sec 2.5. The method showing best results was specialist training, though the results did not sat the EC tolerance restrictions.

3.2. New variables for model optimization

As an alternative solution it was decided to search for new significant variables for bruise prediction. However, this step was difficult as the variables initialy were selected with the parsimony critera as main restriction.

At least an impact tester and an electronic device (IS-100 or DEA-1) would be necessary to evaluate handling procedures and machinery. It was decided, as far as possible, not to add new equipment. Therefore, it was decided to use the variables gathered by the impact tester in order to check whether the models could be improved with them. A bibliography review leads to some recommended variables (Chen and Zongnan,1981; García and Ruiz, 1988; Ruiz Altisent, 1990; Jarén et al., 1992; Correa et al., 1992).

- DFI (5), maximum deformation in impact
- TPI (6), impact duration
- FZI (maximum force in impact)/TPI (7)
- FZI* TPI (8)
- DFI/TPI (9)
- FZI*DFI (10)
- FZI^2/TPI (11)
- FZI/DFI^2 (12)

Also new variables were created on a theoretical basis.

- FZI*TPI^2 (13); (energy dimension)
- **FZC**/FR (14); (deformation dimension)
- **HI**/FR (15); (searching for the impact analogy with 14)
- (FZI*DFI)/**FZC** (16); (deformation dimension)
- **FZC***DFI (17); (energy dimension)
- **FZC^2**/FR (18); (energy dimension)
- FR*DFI^2 (19); (energy dimension)

FZC and HI have been related to the electronic devices records (IS-100 and DEA-1) in Paragraph 4.

To the whole number of variables, 1 to 19, a stepwise regression analysis was applied in order to find out the significance level for bruise prediction. The variables selected (Table 2) always showed a significance level below a 5%. Therefore, the results could not be improved for both compression and impact models of "Golden" or the "Doyenne du Comice" impact models.

With the variables shown in Table 2, new generalist and specialist networks were built (Table 3), searching for a non-linear optimization. The generalist networks covered the whole commercial maturity stage of fruits. As for the specialist solutions, in most cases, it was appreciated that there was a bad learning for an observed damage above two times the EC limit. As this value was quite high, it was decided to train a specialist net only for an observed damage size below that amount. Any unknown individual to be classified would be submitted to a "minimum distance classifier". The decision would be based on the observed damage of the nearest neighbour.

Table 2. New impact variables selected through a stepwise regression analysis. The numbers refer to the variables defined before.

	Model	
Variety	Compression	Impact
"Conference"	1,2,3,7,11,12,14	1,2,3,10,11,15
"Doyenne "	1,2,3,5,14,16	2,3
"Golden"	1,2,3	1,2,3
"Maycrest"	1,2,3,13,14	1,2,3,6,15
"Springtime"	1,2,3,5,9,12,14	1,2,3,5,6,15,19
"Búlida"	1,2,4,7,10,14	1,2,4,7
"Canino"	1,2,4,6,10	1,2,4,10,15

Only for the compression and impact models of "Maycrest" it was shown that the bad learning area was placed around the EC acceptation threshold. This case was more difficult as the threshold area was the most important one. Therefore, it was decided to train a generalist network. Afterwards, a minimal distance evaluation would be made in order to know whether the individuals could belong to the bad trained area or not. In case of belonging to this area, a specialist network would be made to arrive to a final response. The final results for neural approaches are shown in Table 3.

4. RESULTS FOR THE BRUISE SIMULATION PROCESS

As it has been already mentioned in paragraph 2.1, it was necessary to relate the laboratory loading levels with those commonly applied to fruits by handling processes and grading machinery. Lately, Simulated Electronic Products (SEP) have been developed in order to do so (Halderson and Skrobacki, 1986; Brown et al., 1990). Therefore a calibration test was carried out for an IS-100 impact sensig device, as well as for a DEA-1 compression sensing device. In both cases a calibration equation was calculated between the laboratory loads and the electronic devices parameters.

For impact, a calibration equation (Eq.3) was determined where HI is the impacter drop height (cm) of equal energy of the drop height of the IS-100, and AC_{IS-100} is the electronic device acceleration (g). The results showed a correlation coefficient of 0.98 for 127 samples (calibration limits 30-160g).

$$HI=0.347AC_{IS-100}-6.968 \quad (3)$$

Table 3. Final results for the neural approaches. Where: r is the correlation coefficient between predicted and observed damage, n is the number of samples, and "C" and "D" the classification errors of the models; "C" and "D" should be below 10% to accept the model as shown in Paragraph 2.2. The range of values obtained for the correlation coefficient are due to the wide conditions modelized which cover the whole commercial ripening period of fruits.

	Model	
Variety	Compression	Impact
"Conference"	*Specialist*	*Generalist*
	r=0.78;n=480	r=0.82;n=480
	C=5.4%	C=7.5%
	D=6.9%	D=2.3%
"Doyenne"	*Specialist*	*Generalist*
	r=0.72;n=400	r=0.79;n=400
	C=8.5%	C=6.8%
	D=4.8%	D=5.2%
"Golden"	*Generalist*	*Generalist*
	r=0.82;n=456	r=0.88;n=456
	C=7.5%	C=0.7%
	D=4.8%	D=7.7%
"Maycrest"	*Specialist*	*Specialist*
	r=0.79;n=228	r=0.71;n=228
	C=3.9%	C=7.9%
	D=2.7%	D=3.5%
"Springtime"	*Generalist*	*Generalist*
	r=0.81;n=238	r=0.80;n=238
	C=1.7%	C=3.4%
	D=9.2%	D=9.7%
"Búlida"	*Specialist*	*Specialist*
	r=0.64;n=184	r=0.64;n=184
	C=8.2%	C=4.9%
	D=2.2%	D=2.7%
"Canino"	*Specialist*	*Specialist*
	r=0.67;n=139	r=0.68;n=139
	C=7.2%	C=8.6%
	D=2.2%	D=0.0%

For compression, a calibration equation (Eq.4) was determined where FZC is the compression maximum force (N) and R_{DEA-1} is the electrical resistance registered by the electronic device (Kohm). The results showed a correlation coefficient of 0.94 for 252 samples (calibration limits 20-0.4 Kohm).

$$FZC=e^{(5.783-1.338\ln(R))} \quad (4)$$

Finally a simulation process was carried out (Fig. 2-5), were the load threshold necessary to cause damage above the I Class EC limit is 100mm^2 and 50mm^2 for pome and stone fruits respectively; the load limit is measured through the maximum acceleration for impact simulation and through the electrical resistance for compression simulation.

The main results obtained for the bruise simulation process can be summarized as follows:

- there is a great effect of fruit firmness evolution during storage on bruise susceptibility for "Conference" pears (Fig. 2) as well as for peaches and apricots. Firmness evolution did not show this effect for "Golden" apples (Fig. 3) or "Decana pears",

- the effect of fruit firmness evolution on bruise susceptibility is always higher for compression than for impact loads,

- the reference impact loading threshold, damage above the EC limit, for pome fruits reaches 70g while it decreases to 50g when working with stone fruits. These reference values change along the commercial ripening period depending on variety as shown in Fig.s 2 to 5, and

- the reference compression loading threshold, damage above the EC limit, for pome fruits reaches 5Kohmn. Stone fruits show higher compression susceptibility being their loading threshold 20 Kohm (note that the electrical resistance decreases with increasing loading level).

5. RESULTS FOR HANDLING PROCESS AND MACHINERY EVALUATION

Once an acceptable solution (classification error below the EC tolerance level) had been found for each bruise prediction model, an evaluation methodology for handling equipment was designed. This evaluation system consisted of a decision system to aid growers on the knowledge of their procedure and machinery qualities by gathering the information on fruit firmness and storage treatments and relatin it with the records obtained with the electronic devices, IS-100 and DEA-1, for bruise prediction.

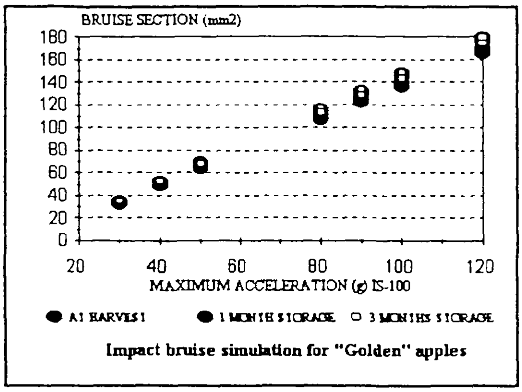

Fig. 2. Impact bruise simulation for "Golden" apples. A low effect of firmness evolution on bruise susceptibility is shown. An acceleration level of 70g leads to damages about the sizes of the EC limit for I Class (100 mm^2).

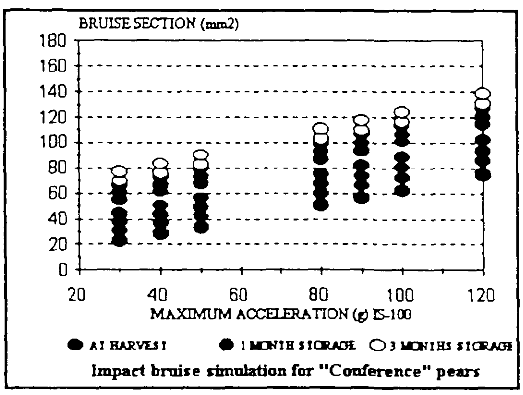

Fig. 3. Impact bruise simulation for "Conference" pears. A great effect of firmness evolution on bruise susceptibility is shown. An acceleration level of 70g leads to damages about the sizes of the EC limit for I Class (100 mm^2); higher level of impact would be needed at harvest to reach the EC limit of damage.

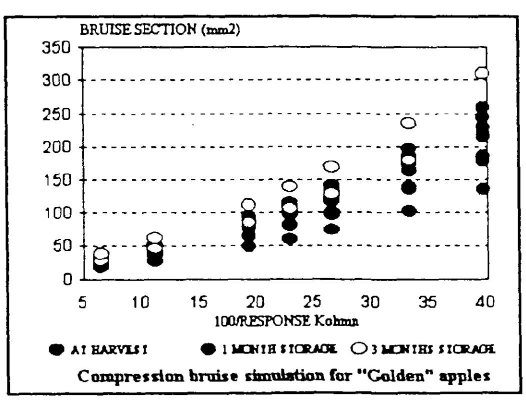

Fig. 4. Compression bruise simulation for "Golden" apples. An electrical resistance level of 5 Kohm (20*100/R) leads to damages about the sizes of the EC limit for I Class (100 mm^2); 3.3 Kohmn (30*100/R) are needed at harvest.

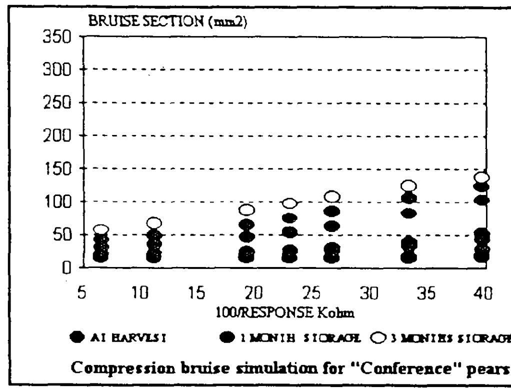

Fig. 5. Compression bruise simulation for "Conference" pears. A great effect of firmness evolution on bruise susceptibility is detected. After 1 month of cold storage an electrical resistance level of 3.3 Kohm (20*100/R) leads to damages about the sizes of the EC limit for I Class (100 mm^2); note that there are no bruise predictions over 200mm^2 due to the bruise range covered by the model, though pears after 3 months storage may show greater bruise values.

Four classes of load levels were created for evaluation:

- **Acceptable loads** whenever predicted damage is between 0-80% of the EC limit,
- **Low risk loads** for predicted damages between 81-90% of the EC limit,
- **High risk loads** for predicted damages between 91-99% of the EC limit, and
- **Rejectable loads** for predicted damages equal or higher than the EC limit.

Once the classes were defined, it was necessary to design the evaluation methodology. As it has already been mentioned, both devices (impact tester and electronic sensors) are used for the evaluation. The electronic devices record the information on the loading levels. However, the number of loading levels registered can be very high, as well as the time needed to process this information. Using the maximum loading level, the process gets faster but the amount of information is reduced. Therefore, it was decided to employ the four maximum loads (L_i) corresponding to each quartil (q_i) of the whole load histogram as a loading selection criteria.

As for the impact tester, the evaluation is made using the information of a mechanical database in order to standardize the comparison between different procedures or machineries.

The number of processed samples is equal to the number of fruits times four (four loads per fruit). The bruise prediction is made on these data obtaining as many damage predictions as processed samples; the whole methodology is described in Fig. 6. Over these results two different evaluations were designed: general evaluation and deficient process or machinery elements assessment.

5.1. *General evaluation*

One fruit needs only one damage above the limit to be rejected. For this reason it was decided to choose the worst damage prediction per fruit to find the potential rejectability of fruits. As there are four different cases of loads defined the results will also be divided in four categories

- -**AC** as the percentage of acceptable fruits,
- -**LR** as the percentage of fruits under low rejectability risk,
- -**HR** as the percentage of fruits under high rejectability risk and
- -**RJ** as the percentage of rejectable fruits.

The Evaluation Criterium was defined acording to the EC tolerance (Eq. 5, 10% in number or weight of fruits for I Class. Whenever the percentage of fruits classified as rejectable or under high rejectability risk is above a 10% a revision or replacement of the concerned process or machinery element is necessary. Also if the percentage of fruits under any rejectability risk is above 20% a revision will be made.

If $HR+RJ \geq 10\%$ or $LR+HR+RJ \geq 20\%$ then revision of the machinery is needed (5)

5.2. *Deficient process or machinery element assessment*

Each of the four selected loadings were decided to be studied through the different percentages of AC, LR, HR and RJ fruits obtained.

A decision system for deficient process or machinery element assessment was created as follows:

1) if the four L_i lead to a further revision (Eq. 5), all the records of the electronic devices above the minimum L_i are identified as needing an improvement. Once the element improvement is made, the evaluation procedure is repeated,

2) if any of the four L_i is within the tolerance criteria, an interpolation for the threshold loading level determination will be made. As before, all the records of the electronic devices above that threshold are identified. After improving the elements, the evaluation procedure is repeated.

3) if all the four L_i are within the tolerance level th final evaluation is positive. Therefore the handlin process or mechanical equipment is acceptable wit respect to the EC Standards.

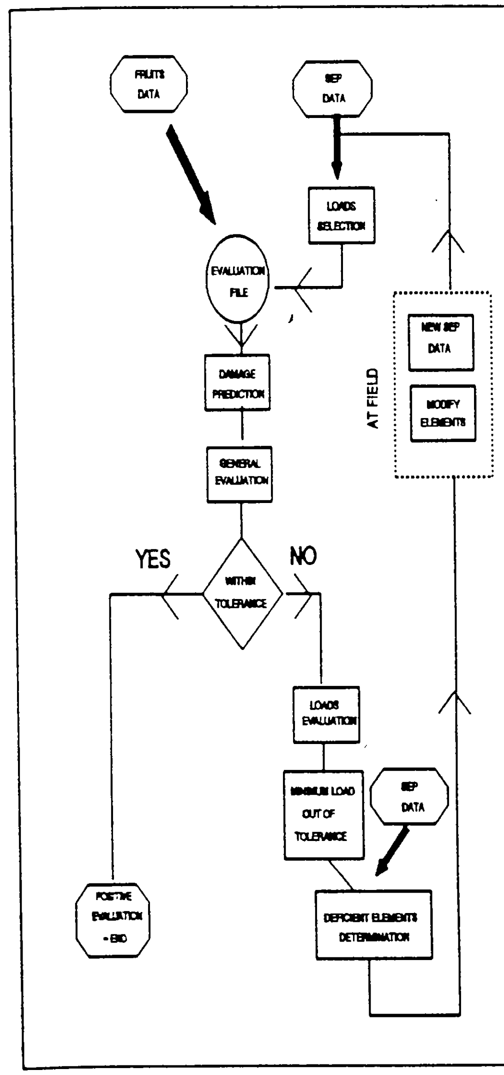

Fig. 6. Evaluation algorithm for fruit handli processes and mechanical equipment. T information on fruit firmness, storage treatment a on electronic devices (SEPs) is put together.

6. CONCLUSIONS

Bruise prediction models have been built, using lin and non-linear regressions as well as feed forwa neural networks, for the main traded species a varieties: apple ("Golden Delicious"), pe ("Conference" & "Doyenne du Comice"), pea ("Maycrest" & "Springtime") and apricot ("Búlid & "Canino").

Those bruise prediction models allow to classi mechanical damages (as acceptable or rejectab under the EC Standards with errors (undetected or overdetected damages) within the EC tolerance threshold, i.e. 10%.

The prediction models gather the information about bruise susceptibility evolution of fruits at harvest, cold storage and subsequent ripenning at room temperature; the whole commercial ripeness range is covered within the models.

The prediction models integrate also information about different loading types (compression or impact) allowing to simulate the effect of loading under different bruise susceptibility conditions of fruits.

A calibration testing was performed to introduce Electronic Products information (IS-100, DEA-1) within the bruise prediction models.

A simulation process was carried out gathering the information on bruise models and impact and compression sensing devices (IS-100, DEA-1).

An evaluation of handling processes and machinery equipment as well as a decision system was built in order to determine current stage of fruit handling processes in relation to fruit physical quality.

7. ACKNOWLEDGEMENTS

To CAMAR Project n° 8001CT91-0206: "Quality of fruits: engineering research for improving the quality preservation during pre and post harvest operations".

To the CEBAS (Murcia) and specially to Dr. Fernando Riquelme for their aid in apricot research.

To the Fruit Cooperative of Montoliu (Lérida) and specially to Mr. Jaume Roque Calzada for their collaboration in pome fruits research.

to ANECOOP (Valencia) for its cooperation in peach research as well as handling process and machinery evaluation.

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