Development of a Prototype for Moulding Paper Trays for Fruit Packaging

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Summary

This communication describes the development of a prototype for a moulding machine for production of paper trays for fruit packaging. Traditionally, fruit pieces are conditioned in plastic or pulp moulded trays for protection against friction (fruit-to-fruit and fruit-to-external packaging) during transportation and handling. Plastic trays may cause problems owing to fruit transpiration and trays made from moulded pulp are expensive and of limited commercial availability. The prototype developed allows for moulding trays on an alternative material - paper, with low energy consumption and in the place of use. Therefore transportation costs are drastically reduced and a just-in-time management can be applied. The prototype includes a continuous paper feeding and transportation system, a set of moulding cylinders that may be changed according to the fruit calliper, and a system for paper extraction and cutting into trays of the desired length. The prototype was designed for moulding Kraft paper of around 70g/m^2 of grammage, it produces around 8 trays/min, and requires one to two operators. The prototype is presently under field testing at an apple producer.

Introduction

"Quinta do Vilar", an apple producer, was looking for an innovative packaging for its product and faced the problem of limited options in the market. Polypropylene trays are widely used (in a typical blue or white colour), yet they may cause problems owing to fruit transpiration. The other commonly used alternative, moulded pulp trays, although yielding better results in terms of mechanical protection and avoiding moisture condensation due to fruit transpiration, are expensive and of limited commercial availability. In addition, a violet colour is typically used, hindering product differentiation in the retail shelves. The idea of producing trays with cells, made up from an alternative material, was then suggested by "Quinta do Vilar" to the Food Packaging Centre of the Escola Superior of Biotecnologia.

Paper was selected as an adequate alternative material: paper is associated to high quality, traditional products, is recyclable and furthermore can be decorated, thus contributing for product differentiation, which is becoming more and more important for ensuring competitiveness. The aim of this work was thus to design and build a prototype of a simple machine to mould paper trays with cells to pack fruits.

Basic design considerations

The prototype was designed so that it could be installed in the apple producer facilities, thus minimising transportation costs and allowing for a just-in-time management. The main operations to be performed by the prototype are schematically shown in Figure 1.

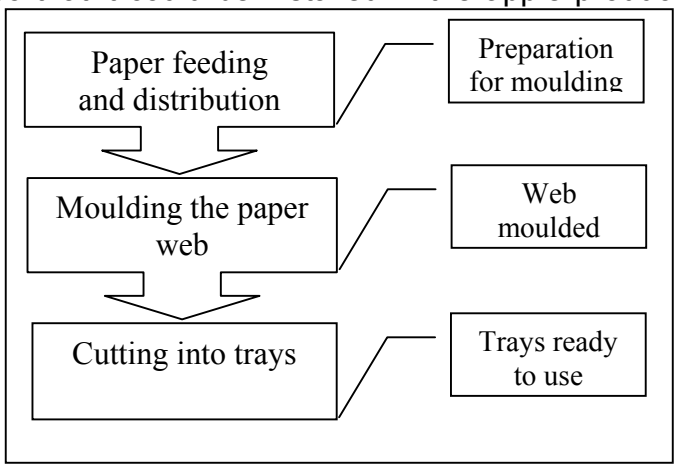

Figure 1. Main operations of the prototype

The main criteria used in terms of the selection of the paper and of the establishment of operation steps and conditions are outlined below.

1. Selection of the type of paper

The paper was selected on the basis of its ability to form cells, humidity absorption capacity and mechanical resistance. Both recycled and Kraft paper and different grammages were considered. Recycled paper was found to form less well and absorb more humidity than Kraft paper, therefore not conferring enough mechanical resistance to the cells. Thus, Kraft paper was selected. In order to further guarantee its mechanical resistance, the Kraft paper grammage was defined as the maximum allowing for good cells formation and a value around 70 g/m^2 was found to be suitable.

2. Selection of moulding conditions

Heating and/or humidification of the paper before moulding were expected to be necessary in order to yield good forming characteristics. The effect of this pre-treatment was tested by exposing the paper to water vapour at 100 ºC for a few seconds, prior to moulding. However, no apparent effects were found on the moulding capability.

3. Moulding steps required

The main problem foreseen was paper tearing in the central web region, due to lack of elasticity. To prevent this, the option of moulding the web in two steps (using two sets of main cylinders) was tested. In the first set of cylinders, the central cells of the web were formed whereas the web edge cells were formed in the second cylinders set. This option was found to be unsuitable, because the second set of cylinders disrupted the cells formed by the first set. Therefore, the alternative of using extra paper in the web centre before a one-step moulding was tested, using the distribution system described bellow.

4. Design of the moulding cylinders

Both the configuration and the material the cylinders were made of were carefully considered. Polyamide was found to be easily workable, allowing for precise dimensions and a smooth surface, and was therefore selected. The

configuration of the cylinders (male and female) was designed taking into consideration the tray standard dimensions (40 x 60 cm), the number of cells required in each tray and their dimensions (both function of the fruit calliper), and the number of cylinder turns required to form the cells. The variables considered were therefore: main cylinders diameter, cylinder pieces diameter and design (to achieve the required depth of the cells) and distribution of the pieces over the main male cylinder.

This distribution could follow either a longitudinal or a transversal alignment, as shown schematically in Figure 2. The transversal alignment was found to be more suitable in the case of a two-step moulding, whereas the longitudinal alignment yielded better results in the one step moulding, earlier selected, and gave a higher number of cells in each tray. The longitudinal alignment was therefore selected.

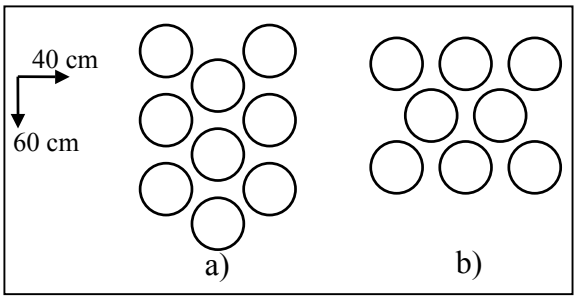

Figure 2. Patterns considered for the distribution of the cylinder pieces over the main male cylinder: a) longitudinal alignment; b) transversal alignment.

The moulding pieces were designed so that the paper cells would be as deep as possible, without tearing the paper. The female cylinder consists in semi-spherical cells with a rounded top edge and a diameter that depends on the fruit piece calliper. The male cylinder is composed by attached cylinder pieces with a spherical top.

Main features of the prototype

A general overview of the prototype is shown in Figure 3. Paper is fed continuously and passes through a transportation system that distributes the paper unevenly, allowing for more paper at the centre of the web and less paper at the web edges. This prevents the paper from tearing during cells moulding, as earlier discussed.

The paper is distributed as it is forced to pass through a metallic corrugated tray and two sets of wheels rolling over the tray depressions (Figure 4). The edges of the paper web are manually folded back at the operation starting and adjusted against metallic guides (Figure 4) in order to get a good finish of the tray edge after moulding.

The paper web is moulded passing through a pair of changeable polyamide male/female main cylinders (Figure 5). The male cylinder is set-up in the upper position, rotating over the female cylinder, as this was found to facilitate the extraction of the moulded web before cutting into trays (Figure 6). The cylinders rotating speed is adjustable, a lower speed being used at the start-up (allowing for introduction of the paper between the main cylinders) and a higher speed being used during moulding paper, with temporary stops for cutting. The clearance between main cylinders is also adjustable.

After moulding, the web is transversally cut into trays with a length that may be adjustable but usually set up at 60 cm. The cut is made with a blade that is synchronised with the main cylinders rotation (Figure 7).

The specifications of the paper, working requirements and general characteristics of the prototype are summarised in Table 1.

Table 1. General characteristics of the prototype

Recommended paper characteristics	Type: Kraft Grammage: 70 g/m^2 Tensile resistance: 5.5 N/mm (MD) 3.0 N/mm (TD) Rolls: 70 cm length, 20 kg maximum
Working requirements	Electric current 220V Air pressure: 9 - 11 kg Nº of operators: 1 - 2
General Characteristics	Main dimensions: 280 x 170 cm Moulding cylinders in polyamide: 42 cells/tray for fruit calliper 70/75 35 cells/tray for fruit calliper 75/80 Production: ~8 trays/min Power consumption: 1.2 A (260 W)

Conclusions

The prototype developed allows for moulding trays on an alternative material - paper, with low energy consumption and in the place of use. Therefore transportation costs are drastically reduced and a just-in-time management can be applied. The prototype is presently under field testing at “Quinta do Vilar”, paying particular attention to the degree of protection this type of package offers to the fruits, and assessing the influence of typical storage conditions (low temperature and high humidity) on the packaging performance.

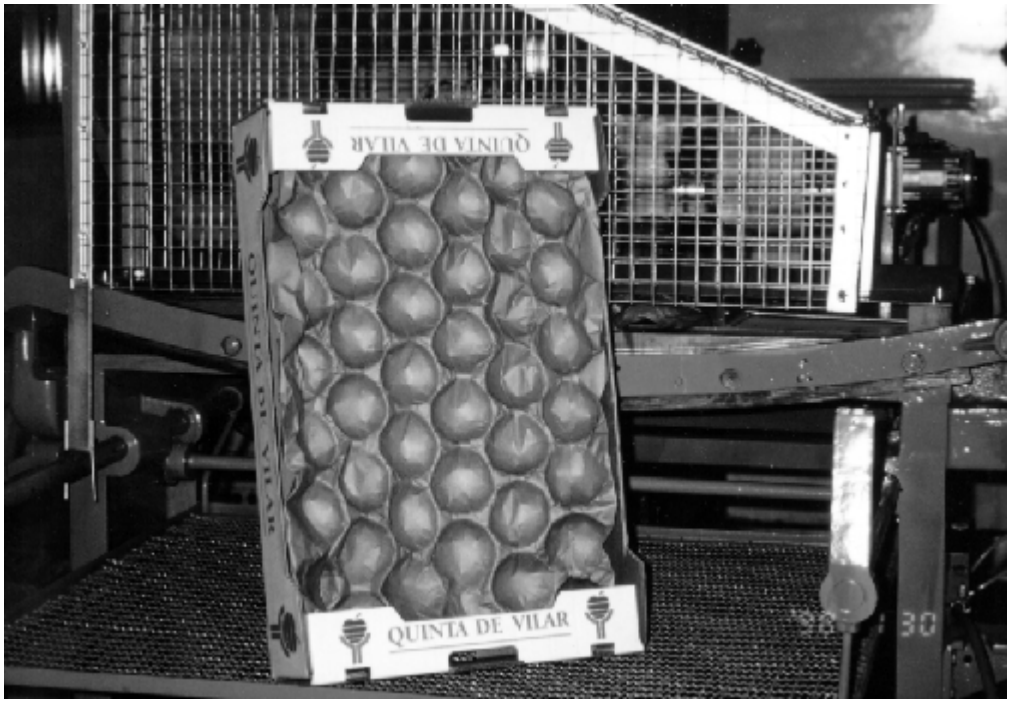

Figure 3a. Moulded paper tray inserted in corrugated transportation tray.

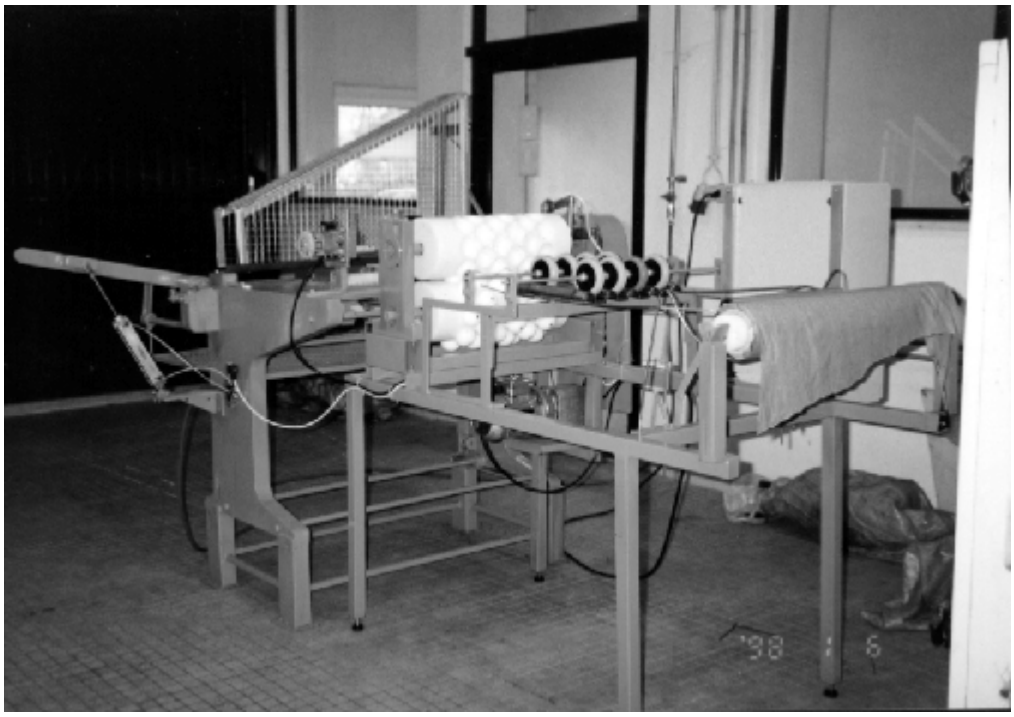
Figure 3b. General overview of the prototype.

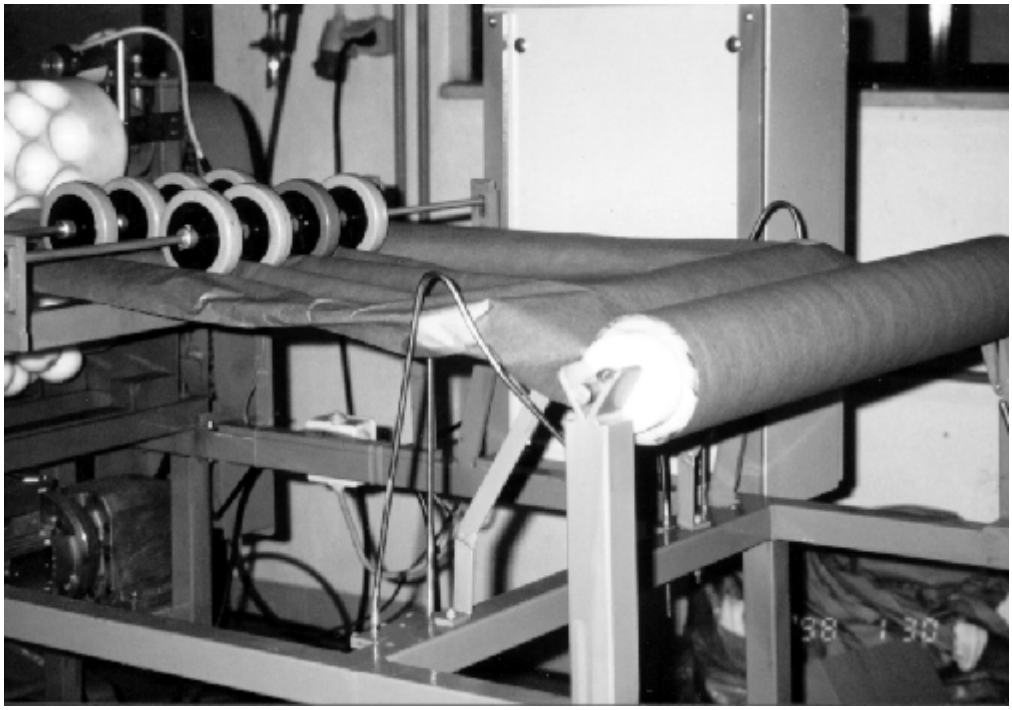

Figure 4. Paper distribution before moulding and metallic guides.

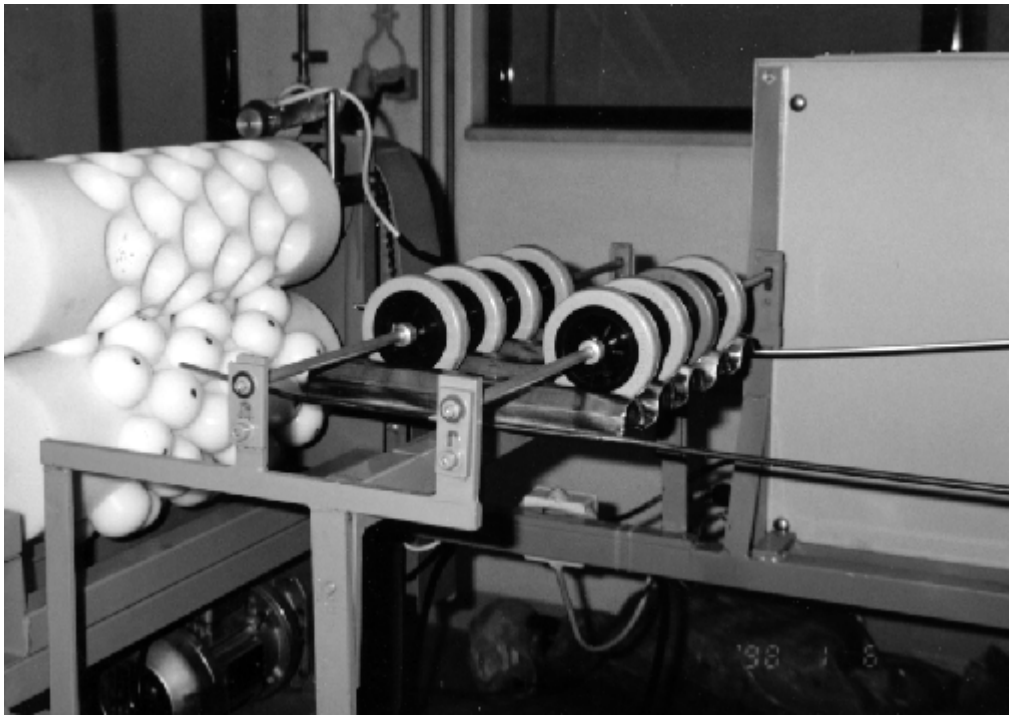

Figure 5. Main moulding cylinders

Figure 6. Paper web extraction after moulding.


Figure 7. Paper web cutting into trays