# Almond Waste: A New Ecology-friendly Alternative Substrate in Tomato Culture

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## Abstract

**The woody endocarp of almond fruits is a waste product for which no important industrial uses have been developed and previously it has been incinerated or dumped without control. In the current study, tomato plants were grown in a plastic-house under semi-arid conditions in the South-East of Spain. Different agricultural systems, coconut coir bags and almond waste bags, were tested in order to optimise the use of water and fertilizers, to minimize environmental pollution and increase the quality of fruits. The effect of both systems on yield and fertigation requirements was evaluated and discussed in terms of environmental factors. The results suggested that no important differences were present. Therefore, almond waste residues seem to be an acceptable substrate substitute for peat and rockwool in soilless crops.**

## INTRODUCTION

Maximum quality and environmentally friendly production methods are required in intensive horticulture. Different programmes have been developed to improve production practices including: collection and treatment of crop residues, extraction and storage of water and irrigation equipments. In soilless culture, many improvements have been recently adopted such as the use of substrates with potential for re-use or recycling.

The coast of Almería is an arid area in which agriculture is difficult. However, new technological improvements have made agricultural development possible. Recently, industrial mineral substrates like rockwool and perlite have been introduced in the area, but one major problem associated with soilless culture is the residues generated by the materials used as substrates. From an environmental point of view the most important criteria in selecting a substrate material for soilless horticulture should be durability and potential for recycling. Generally, substrates of limited availability, troublesome management, phytotoxicity, variability, instability, and high cost are rejected. Coconut coir is a by-product of the coconut industry, which is available in high amounts in the producing countries. In Almería 5000 t of residues and by-products of the almond industry, are generated between September and May each year. These granular materials are woody, ridged, porous and very rich in fibre and lignin.

The major objective of this work was to evaluate the feasibility of using crushed almond shells as a growing medium in intensive horticulture in SE Spain. To do so a comparative evaluation of a tomato crops grown on two organic substrates and managed according to commercial practice, was conducted to determine yield and drainage composition in order to quantify losses to the environment.

## MATERIAL AND METHODS

The experiment was conducted in a symmetric multispan greenhouse (gutters running N-S) located in El Ejido (SE Spain). Total area of the greenhouse was 22425 $m^2$. In this experiment we used two organic substrates, coconut coir and almond shells. The volume of the crop units (bags) were 40 L and 18 L respectively. Tomato plants (*Lycopersicon esculentum* cv Daniela) were sowed on the $20^{th}$ September and transplanted on the $2^{nd}$ November 2000. Plant density was 1.5 plant $m^{-2}$ with 4 plants per bag. The nutrient solution had the following characteristics: EC 2.31 dS $m^{-1}$, pH 5.74, and

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concentrations (in mmol $L^{-1}$) of 14.04, 2.00, 3.05, 8.00, 5.00 of $NO_3$, $H_2PO_4$, $SO_4$, Ca and Mg, respectively. Water was applied with a localized irrigation system; pH, EC, time and frequency of irrigation were automatically adjusted depending on crop developmental stage. Drainage volumes and EC and pH were determined weekly. Chemical analysis of drainage and nutrient solutions was conducted every fortnight by ionic chromatography. Harvest started on the 23rd February and finished the 18th May 2001. Yield was graded according to EU regulation 778/83. Fruit grading was done using the maximum equatorial diameter; for tomatoes a minimum calibre of 35 mm is required, with a scale of 35-40 mm, 40-47 mm, 47-57 mm, 57-67 mm, 67-82 mm, 82-102 mm, and. larger than 102 mm. Two different groups of marketable and non-marketable fruits were established. Total and early yield were measured and details of fertigation inputs and drainage were recorded. The experimental set up was a randomized complete block design (Little and Hills, 1976; Petersen, 1994) with two treatments (almond shells and coir) and four replications. The criteria of Little and Hills (1976) and Petersen (1994) were adopted in the analysis of variance of the experimental designs. The t-Student probability was adopted in mean separation of the different treatments.

## RESULTS AND DISCUSSION

Table 1 shows the average properties of drainage water: EC, pH and drainage fraction, and total volume added to the system. Drainage fraction during the whole cropping cycle was 67% in almond shell and 35% in coir. However, it should be noted that the volume of the bags differed (40 L coir and 18 L almond shell). To determine differences in management of each of the substrates, chemical and physical properties should be known (Abad et al., 1993, Abad et al., 2002). The drainage EC (Table 1) was very similar in both substrates, although EC of drainage water from coir increased over the growing season. The pH of the drainage water (Table 1) was significantly lower for coir compared with almond shell. Noguera et al. (2000) described coir as a slightly acid substrate, with initial pH values between 4.9 and 6.14; this could explain the differences. The pH of almond shell waste was slightly higher than 7. However, EC and pH of drainages from both substrates was in the range of acceptable values.

Table 2 shows total water leached or drained from both systems during the growing season. Absolute losses were twice as high from the almond shell compared to the coir substrate (Table 2). However, it is important to consider the differences in bag volume of both substrates and in their water holding capacity in relation to porosity (De Boodt et al., 1974). The total volume of water used by the coir system was twice that of almond shells (Table 1).

Because drainage water was not recycled, it was necessary to study losses of water and environmentally polluting agents during the whole cropping cycle. Water is a limited resource and fertilizers can pollute soils and aquifers. Table 2 shows the total losses of nitrates and phosphates from both substrates. Almond shell drainage water contained higher concentrations of nitrates and phosphates than coir drainage water, probably due to the high drainage fraction of this substrate. The total nutrient loss from the almond shells was higher, due to excessive rinsing of this substrate and the need to optimize irrigation management. In absolute terms, losses from almond shells of nitrates (greater than 137 g $m^{-2}$), and phosphates (greater than 30 g $m^{-2}$), were much above those from coir.

Fertilizers applications were high compared with the experiment of Bartosik et al. (1993), who determined losses of 683 kg $ha^{-1}$ of nitrates and 11 kg $ha^{-1}$ of phosphates. If we consider previous works by García and Urrestarazu (1999) in which three different irrigation systems were studied: open, 100% closed and intermediate; the values of drainage fraction found in a open system are similar to those of the current study, although slightly lower due to the length of the cropping season.

Table 3 shows total and early yield, sorted by fruit diameter. Early yield of plants growing on almond shell was significantly higher ($P$ = 0.0027) than that of coir. Number of early fruits with diameter 57 - 82 mm was greater for the almond shells than for the coir treatment, ($P$ = 0.0023). Non-marketable yield was significantly higher for coir than for almond shells. However, if total yield is considered, there were no significant differences between treatments. Observed total yields of 12.6 kg m$^{-2}$ for the almond shells substrate and greater than 13 kg m$^{-2}$ on the coir substrate, are similar to the expected values for other substrates in general use. It can be concluded that almond shells can be used as soilless substrate if we adapt fertigation management to match the characteristics of this substrate.

## CONCLUSIONS

According to the yield results the use of organic substrates in soilless culture, in order to improve environmental sustainability, is feasible. It is very important to control drainage fractions to avoid waste of water and nutrients. The physical-chemical and chemical parameters of almond shell substrate obtained in this trial do not differ much from those of other substrates such as perlite and rockwool. It can be concluded that growers experienced in the management of soilless culture will be able to adapt to growing on with bags with almond shells. Leaching to the environment can be minimized by an adequate control of drainage fractions and their composition, and adapting irrigation to physico-chemical properties of each substrate.

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## Tables

Table 1. Daily mean drainage water quantity and quality and fertigation applied to the system (VI) in a tomato crop (*Lycopersicon esculentum* cv Daniela) on two substrates: coir waste (CW) and almond shells (AS). SD= Standard Deviation.

| | Drainage | | | | | | VI | |
|---|---|---|---|---|---|---|---|---|
| | % | | EC | | pH | | L m$^{-2}$ cycle$^{-1}$ | |
| | CW | AS | CW | AS | CW | AS | CW | AS |
| Mean | 35.51 | 67.22 | 2.65 | 2.44 | 6.64 | 7.32 | 225 | 118 |
| SD | 0.52 | 1.80 | 0.03 | 0.04 | 0.05 | 0.04 | 2 | 6 |
| *P* | 0.0186 | | 0.0895 | | 0.0491 | | 0.0088 | |

Table 2. Total losses to the environment of anions and water (DV) in a tomato crop (*Lycopersicon esculentum* cv Daniela) on two substrates: coir waste (CW) and almond shells (AS). SD= Standard Deviation.

| | Anions (g $m^{-2}$) | | | | DV | |
|---|---|---|---|---|---|---|
| | $NO_3^-$ | | $H_2PO_4^-$ | | L $m^{-2}$ | |
| | CW | AS | CW | AS | CW | AS |
| Mean | 94.36 | 137.64 | 19.50 | 30.56 | 116 | 223 |
| SD | 0.35 | 8.44 | 2.64 | 0.70 | 2 | 5 |
| *P* | 0.0868 | | 0.0888 | | 0.0088 | |

Table 3. Sorted early and total yield (g $m^{-2}$) in a tomato crop (*Lycopersicon esculentum* cv Daniela) on two substrates: coir waste (CW) and almond shells (AS). SD= Standard Deviation.

| | | Diameter (mm) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 82-102 | | 58-82 | | 57-67 | | 47-57 | | Non marketable | | Total | |
| | | CW | AS | CW | AS | CW | AS | CW | AS | CW | AS | CW | AS |
| Early | Mean | - | - | 63 | 125 | 141 | 234 | - | 31 | 47 | 23 | 250 | 414 |
| | SD | - | - | 38 | 0 | 16 | 16 | - | 22 | 16 | 14 | 44 | 34 |
| | *P* | - | - | 0.0663 | | 0.0003 | | 0.0917 | | 0.0981 | | 0.0027 | |
| Total | Mean | 1125 | 891 | 2820 | 3156 | 4516 | 4742 | 1656 | 1938 | 2977 | 1938 | 13094 | 12633 |
| | SD | 234 | 307 | 95 | 190 | 367 | 343 | 240 | 330 | 419 | 295 | 545 | 334 |
| | *P* | 0.3364 | | 0.0468 | | 0.4650 | | 0.2816 | | 0.0023 | | 0.0154 | |