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Processing yield of the carrot cultivar Esplanada as affected by harvest time and planting density

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Abstract

Cenourete® is a minimally processed carrot root similar to the American product known as 'baby-carrot'. This product is obtained through peeling and abrasion of cylindrical carrot root segments. The cultivar Esplanada is well suited for the production of Cenourete® due to its characteristics of long length and cylindrical root shape as well as uniform dark orange root colour. For Cenourete® production, the root should be less than 25 mm in diameter. However, it is well known that root size is influenced by planting density and harvest time. Therefore, the adjustment of the cultural practices would be necessary to increase root yield aimed for Cenourete® processing. The recovery of Cenourete® from 'Esplanada' was studied under two between-line spacings: 20 cm (5 transversal lines/m) and 12.5 cm (8 transversal lines/m). Roots were harvested at 80, 90, 100 and 110 days after sowing. Cenourete® yield ranged from 2.39 ± 0.37 to 10.75 ± 1.07 t/ha depending on the combination of harvesting date and between-line spacing. These values corresponded, respectively, to a percent Cenourete® yield recovery of 3.3 ± 0.7%–28.6 ± 2.8% in relation to the total root production. It was concluded that higher yield is obtained with 12.5 cm between-line spacing than with 20 cm between-line spacing and with earlier harvest (80–90 days) than with late harvest (100–110 days).

Keywords: *Daucus carota*; Fresh-cut carrot; Harvest time; Population density; Cenourete®

1. Introduction

The Brazilian carrot cultivar 'Esplanada' is an open pollinated variety, which combines adaptation to tropical environments and high levels of resistance to leaf blight and moderate resistance to root-knot nematodes (Vieira et al., 2005). 'Esplanada' was developed for industrial processing as a special mini-carrot item named Cenourete®.

Cenourete® is a registered trademark. Both the technology and equipment for its production were developed by the National Center for Vegetable Crops Research (CNPH), Embrapa, Brazil. The production system of Cenourete® consists basically in cutting the carrot root into 60 mm long cylindrical segments which are afterwards polished with an abrasive surface (Lana et al., 2001). After abrasion, the segments take the shape of miniature carrots (Fig. 1) similar to that of the ''baby carrot'' sold in the USA market. Different from the ''baby-carrot'', the Cenourete® system is suitable for production by small industries using low-cost equipments.

Marketable yield of Cenourete® is mainly dependent upon root size. The longer and thinner the root, the higher is the recovery of processed product. Top quality carrot roots (in the raw state) for Cenourete® production are obtained from segments that have diameter equal or lower than 25 mm (Lana et al., 2001). Segments with a diameter between 25 and 30 mm can be used to produce a larger Cenourete® product, which is more suitable for cooking. Root segments larger than 30 mm will result in products with poor visual quality and with higher consumption of energy in order to attain marketable requirements.

With a planting density (plant stand) of 700.000–750.000 plants per hectare and with roots being harvested at 90 days after sowing, the carrot cultivar 'Esplanada' can reach yields between 30 and 35 t/ha. On average, the roots at this stage are 200 mm long with a diameter of 30 mm (Vieira et al., 2005). However, there is no information about the predominant root shape and size under this growing condition. This information is relevant since only roots segments with diameter lower than 30 mm are suitable for processing as Cenourete®.

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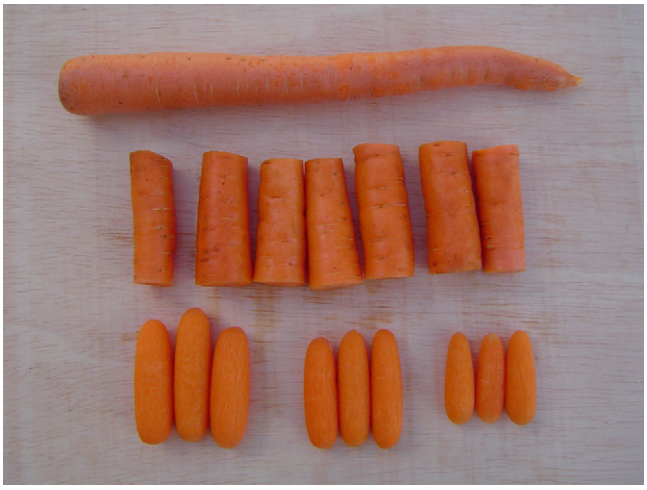

Fig. 1. Carrot root (upper row), unprocessed root segments 6 cm long (middle row) and Cenourete® (bottom row).

The size variability of individual carrot plants is influenced by both plant density and time after sowing (Li et al., 1996). In general, higher planting density results in smaller plant size and a lower root mass (Lima et al., 1991; Silva et al., 2003; Rajasekaran et al., 2006). Studies with the slicer variety 'Caro' and the dicer variety 'Chantenay' showed that both seeding rate and line spacing are able to influence the recovery of distinct root grades (Rajasekaran et al., 2006). It is well known that root size is also a result of harvesting date. Carrot roots attain maximal primary growth (length) up to 50 days after sowing and maximum secondary (radial) growth after 50 days. Cultivars from 'Brasília' group, when grown at the population density of 700.000 plants per hectare and harvested 110 days after sowing produce roots with average diameter of 35 mm (Vieira, J.V., unpublished data). Root size at harvest was the main factor affecting the yield of cut-and-peel (baby carrots) yield in the cultivar Caropack at a range of sowing densities (Lazcano et al., 1998).

In view of that, it is hypothesized that it is possible to increase the recovery of roots with less than 30 mm diameter by optimizing both planting density and harvesting date for Esplanada cultivar. This study examines the combined effect of number of lines per bed and harvest time on root yield, root size and Cenourete® yield.

2. Materials and methods

Carrot seeds of the cultivar Esplanada were sown by hand in 1.2 m wide beds during the summer of 2004 at the CNPH's Experimental Field in Brasília-DF, Brazil. Number of transversal lines was either 5 or 8 lines/m. Five lines per bed is the predominant system in commercial carrot fields in Brazil. Distance between lines was as follows: five lines/bed, 20 cm, 8 lines/bed, 12.5 cm. Thinning was performed 25 days after sowing leaving 20 plants/m within each line what corresponded, respectively, to 700.000–1.120.000 plants per hectare. Each plot was one 8 m long bed, laid out in a fully randomized block design with four replications. All cultural practices were done as recommended by Vieira et al. (1997).

Roots were harvested 80, 90, 100 or 110 days after sowing. All roots were washed, counted, weighed and classified into two classes: large roots (wider diameter >25 mm) and thin roots (wider diameter <25 mm). Each class was counted and weighed separately. All roots were pooled, cut into 60 mm long cylindrical segments using a Precisa (Silva and Vieira, 2004) cutter and later classified into three classes: (1) cut waste: crowns, tips, segments shorter than 60 mm, segments wider than 30 mm, segments with defects such as green parts, cracking, discolouration and misshape; (2) large root segments (diameter between 25 and 30 mm) and (3) thin root segments (less than 25 mm diameter). Both categories of root segments were processed separately for 1.5 min using the Múltipla (Silva and Vieira, 2005) peeler producing, respectively, Large and Thin Cenourete®. Both classes of Cenourete® were weighed separately.

The yield, expressed as percentage weight, was calculated at two steps in the processing line. (1) Root Segment Yield is the weight of root segments produced in relation to the total root yield; (2) Cenourete® Yield is the weight of Cenourete® produced in relation to total root yield both in t/ha. The difference between (1 and 2) corresponds to the amount of carrot tissue removed from the root segments by peeling and was named peeling waste in the present work. The sum of cut weight and peeling waste is equal to the total waste in the production of Cenourete®.

Data analysis was performed using PROC GLM from SAS (SAS Institute, 9.1 for Windows) at a significance level for the analysis of variance tables at $P > 0.05$. The R^2 statistics was calculated according to (Hatcher and Stepanski, 1994), indicating the proportion of variance in the criterion variable that is accounted for by the study's predictor variable (s). Values of R^2 ranged from 0.00 to 1.00, with larger values indicating a larger treatment effect. Mean separations were analysed by Tukey test at $P > 0.05$.

3. Results and discussion

The final number of plants per hectare was lower than the targeted 700,000 plants for 5 lines and 1,120,000 plants for 8 lines. On average it reached 606.000 plants and 857.000 plants per hectare, respectively, for 5 and 8 lines/m. Population varied with between-line spacing ($\Pr > F = <0.0001$) while the effect of harvesting date was not significant ($\Pr > F = 0.6100$) nor was the interaction ($\Pr > F = 0.2951$). Although the target population size was not attained, the difference between treatments was achieved.

Total root weight increased with harvest delay up to 100 days after sowing ($\Pr > F = <0.0001$) and was only marginally affected by between-line spacing ($\Pr > F = 0.0284$). A slightly higher yield was found at 12.5 cm compared to 20 cm (Fig. 2). Delaying harvest from 80 to 110 days resulted in an increase in total root weight from 30.64 to 70.24 t/ha with 5 lines/bed and from 36.04 to 68.51 t/ha with 8 lines/bed. The increase in total root production did not result in higher yield recovery of Cenourete®, a relation also reported by Lazcano et al. (1998) with cultivar Caropack for 'baby-carrot' production.