Economic evalution of loading systems for citrus destined for industrial processing

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ABSTRACT

Citrus production for frozen concentrated orange juice (FCOJ) has many options for loading oranges in harvested fields. There are several questions about the available systems, regarding their adaptability to the farm, economic costs and trees health. Through a field survey and simulations of each found system, for different production levels (farm size), it could be evidenced that the systems with a considerable mechanization level are the most economic ones, with notable scale gains. Systems that dissociate the harvesting and loading showing economic and strategic advantages, considering the increasing possibility of the period for orange trucks leaving the farms, reducing trucks arrival peaks in juice plants and easing the waiting problems in factory lines. The best option for orange loading varies depending on farm production level, equipment investments, management and prevention of health risks.

Index terms: *Citrus* spp., logistics, harvest, cost.

RESUMO

Análise econômica dos sistemas de carregamento de citros para processamento industrial

A citricultura industrial, para a produção de suco de laranja concentrado e congelado (SLCC), dispõe de diversas opções para o carregamento das laranjas colhidas no campo. Há questionamentos diversos sobre cada um dos sistemas disponíveis no que tange à sua adaptabilidade à fazenda, à economicidade e à sanidade do pomar. Através de levantamentos a campo e simulações dos sistemas encontrados, para diversos níveis de produção da fazenda (escala), evidenciou-se que os sistemas mais econômicos seriam aqueles com nível considerável de mecanização, sendo notáveis os ganhos de escala. Sistemas que desvinculam a colheita do processo de carregamento além de demonstrarem vantagens econômicas, também demonstram vantagens estratégicas para fazendas e indústrias, levando em consideração a possibilidade de aumento do período de saída de veículos carregados da fazenda, reduzindo assim os picos de chegada de veículos às fábricas e amenizando problemas de fila. A melhor opção de carregamento varia conforme o nível de produção da propriedade, do investimento em equipamentos e do risco sanitário que se deseja evitar.

Termos de indexação: *Citrus* spp., logística, custo.

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INTRODUCTION

Brazil is the largest citrus fruit producer responsible for 28% of world's orange production (FAO, 2008). There are many citrus fruits loading systems aiming its process delivery. These methods stand out because of equipments' variety and the structures involved in the process. Since simple loading - totally manual, using personal harvesting bags supporting 20 kilos capacity and loading them directly to the truck - passing through systems that already use some mechanic implementation and others that already use big bags (generally with 500 kilos capacity), which are elevated by hydraulic winch, unloading directly into trucks or in transshipments. It is understood by "loading" the activity that makes the fruits harvested from the trees and placed in bags by the pickers, available to transport systems, being directed to industries or to *bins*[1]. The costs involved in each system include expanses in usage materials, such as bags, manpower (including social charges), mechanized equipments and infrastructure (bins).

According to AgraFNP (2009) the harvest and citrus loading costs is equivalent to 21,2% of the total production. There are many doubts regarding which system to use, not only considering direct costs, but also today is taken into consideration the orchard's sanitary aspects, specially those regarding prevention against bacterial diseases, mainly citrus canker as well as the supply tune with factory demand. The use of mechanized systems can amplify loading period in the orchard because it separates harvest manpower from loading.

This paper aims to identify the loading systems currently used in São Paulo's citrus cultivation and to analyze the economic viability of each one of them. Detailed field information and equipment information were raised and the total loading costs were estimated. According to property loading system, some harvest characteristics are modified. In Brazil, as well as in the US, the harvest is almost entirely manual (Whitney, 1999; Molin & Mascarin, 2007). The economic analysis of loading systems made by Tachibana & Rigolin (2002) has estimated that when mechanized systems are used, it is important to make its use economically viable, aiming for high equipment productivity, mainly reducing its downtime. Regarding costs, considering the forest loader and manual system, when compared to property's production level, the production increase the use of a mechanized system is clearly more economic then manual one, denoting scale gains of these options.

MATERIALS AND METHODS

To characterize the loading systems, 21 farms were visited in the so called citrus belt (Neves et al., 2007) in São Paulo state, where the harvest dynamic and each loading system adopted by each farm was observed and studied. All systems' details and technical coefficient were raised, trying to get to know them thoroughly. The field data was collected from December 2007 to May 2008. Figure 1 shows the localization of the farms visited during the survey period.

Figure 1. Visited towns during the field search stage indicated in São Paulo's map.

Different size farms were considered, thus the main parameter was a representative average of boxes[2] quantity, produced by the farm in one agricultural crop. For each farm size was calculated the equipment quantity, structure and personnel needed using these parameters: i) size of the harvest team: 40 people; ii) daily harvest capacity per team: 4 trucks/day; iii) truck's capacity: 440 boxes; iv) average farm productivity: 32 ton/ha (785 boxes/ha); v) bags durability: 2 crops; and vi) capacity of each bin cell: 36 tons.

[1] *Bin* is a large storage structure for fresh oranges, which can be installed in farms.

[2] A "box" is a standard unit, corresponding to 40.8 kg of oranges

Regarding the harvesting teams, besides interviews with sector agents, aiming to know the quantity of teams per farm according to its size, was also made a simulation considering productivity, number of harvesting days necessary to harvest all farm's production, as well as the number of necessary teams to implement the activities, within seven months maximum period, which is when concentrate the biggest harvest part in Sao Paulo state. The considered data is the model that can be observed in Table 1.

Table 1. Harvest teams' quantity considered quantity per representative farm size (each team compound by 40 workers; a box contains 40.8 kg of citrus fruit).

Citrus production (boxes)	No. of teams
5 to 150 thousand	1
151 thousand to 350 thousand	2
351thousand to 500 thousand	3
501 thousand to 700 thousand	4
701 thousand to 850 thousand	5
851 thousand to 1 million	6
1,5 million	10
2 million	12
2,5 million	15
3 million	18
3,5 million	20
4 million	20
4,5 million	20
5 million	21
5,5 million	23
6 million	25
6,5 million	27
7 million	29

The costs calculus methodology used was the one suggested by Matsunaga et al. (1976), which considers not only the equipment costs, but also their depreciation for each kind of equipment involved in the system, the payment for invested capital and all manpower costs involved, direct and indirect. It is possible to obtain costs per box for each one of the systems, according to farm size (boxes to be harvested). When the electrical energy costs was required to estimate bins' working costs, it was used the average value charged in the state (R$0,15 kW/h), among many concessioner that operates in that sector.

When transport in the farm was needed (to complement the loading systems to the bins), the logistic costs were calculated using the methodology described by Lima (2003). In this methodology is considered fixed costs (depreciation, payment over invested capital, manpower costs, taxes and insurances) and variable (tires, fuel, engine oil and differential, washing, maintenance), compounding the cost per hour per vehicle (considering an average speed of 30 km/h in internal drive, this information was given by the drivers themselves). Also considering the time costs when the vehicle was downtime (waiting for loading and unloading), this time was considered 2,5 hours in average per journey. The considered vehicle was a 15 tons truck maximum capacity. All data price that fed Lima's transportation model (2003) were collected by ESALQ-LOG group (2008), by market research during July 2008 (monthly average tax rate: US$ 1,00= R$ 1,5914).

The different identified loading systems received the name "S1"... "Sn", going from the simpler one (with no or few mechanization in loading operation) to the most complex one (more mechanized loading operation).

For S1 costs, the loading is essentially manual, information were gathered from sector agents, considering all involved manpower costs, establishing a cost per harvested box paid in crop season 2007/08.

The costs calculus of bin's manpower was important for this paper. It was defined, after an interview, information with sector agents and molding the necessary numbers of employees for the operation, according to their size (who operates loading and unloading, and some other operational details, such as fill out information on the receipt). The group dimensioned it according to each farm needs. The bin's costs (acquisition, installation and

cell number), as well as electrical energy costs, vary according to its size. A price survey of used equipment - with a standard cell capacity of 36 tons - was done through a quotation in the main manufacturer of São Paulo state.

It is important to highlight that the bin was considered the "lung", which means that, it represents some storage capacity, serving especially for better sanitary control and for a longer daily period fruit offer to the transport system. Once the orange harvest is manually done and that employees can work only 8 hours a day by Brazilian labor regulations, there is a concentration of fruit supply from farms to processors during this narrow day period. The bin can works as flow regulator, allowing orange supply in different period (during 24 hours a day, for example) than the one restricted to harvesting. Besides this better supply flow control, the bin enables the fruit transfer among trucks, allowing some trucks to be restricted to one unique farm, reducing significantly the bacterial contamination risk, by travelling to other farms or even at the discharge moment at the processor's platform.

Electronic spread sheets were elaborated using Microsoft Excel® software which considers production level and all necessary equipments to fulfill the farm needs, calculating the costs in each system.

RESULTS AND DISCUSSION

The field research allowed the identification of eight (8) loading systems, as follows:

S1. Manual traditional: Consists basically on harvest loading satchel directly into the truck's wagon, and all the process is manual, requiring specific harvest team members for this activity. In this system, the only vehicle used is the truck and it access the orchard interlines.

S2. Manual with bin-wagon help: The loading is similar to manual, however with an intermediate equipment that consists of a wagon pulled by a tractor that is equipped with oranges' elevation system (elevator), similar to the elevators used for other fruits (touched by the tractor's TDP), which loads the truck. The equipment also enters in the orchard interlines;

S3. Manual in the farm with bin: Similar to S1, however considering the vehicles (trucks) that access the orchard cannot leave the farm (to avoid phyfitosanitary contamination risks), unloading the fruits in the bin that works as a middleman, to later, load the other vehicles that go to factories (it might not attend bigger vehicles such as wagons and bi-trains);

S4. Manual with bins and bin-wagon help: It is basically S2 with the bin (S3);

S5. Mechanized without transshipment: This system is different from the others, especially because it uses the bag, which is supplied by the harvest satchel and later unload in the truck (which access to the orchard interlines), with the use of an adapted tractor of a hydraulic lift system with a winch. This systems requires a tractor driver that operates the so called "crane" or "spear";

S6. Mechanized without transshipment with bin in the farm: Similar to S5, adding the presence of a bin isolating harvesting vehicles from the ones that transport to the industry and enabling the bigger vehicles use;

S7. Mechanized with transshipment: This system is more modern, currently used in large scale citrus-culture. The big bags (proximally 500 kilos capacity that are fed by the harvesting satchels) are loaded with a "crane" help of systems S5 and S6, in transshipment like the ones used in sugarcane harvest (donated equipments from hydraulic lifting and toppling systems, to facilitate loading and unloading). Each one of the aforementioned (crane and transshipment) needs a tractor, and the system usually needs 2 transshipments; one set of harvest works with 3 tractor. The loading is made in a track (orchard's "road"), it can also be done with bigger vehicles (wagons and bi-trains) directly;

S8. Mechanized with self loadable: Consists basically on a more compact and advanced version of S7, reducing the number of involved tractors for the transshipment itself, it already has a hydraulic lifting arm. The set of harvest used is normally made of only one vehicle (self loadable transshipment attached to the tractor). The truck loading is also made in a track, isolating it from the orchard.

On Table 2 there is a summarized description of each one of the systems aforementioned, with the sequence the harvested fruit passes by.

It is convenient to bear in mind that the main orange production costs (Neves et al., 2004) are related mostly to phyfitosanitary treatment, and there could be reduction in these stages adopting a less risky loading system.

Regarding internal transportation, complementary to systems that uses bin, the overhead cost found was R$ 27.94/hour and the variable cost R$ 1.0417/km. These data considers a truck with maximum liquid capacity of 15 tons. The bin presence, although gives logistics (the farm's "lungs") and phyfitosanitary (avoiding loading vehicles to leave the farm) advantages, it elevates substantially the overhead costs with internal transportation.

Two important aspects to be considered arethat the bin size that will be installed to attend the farm's and, consequently, the number of people involved, peopleand if there is the needneeded of two working shifts using bins. On table 3 it is possible to observe the obtained numbers with molding system.

From each production scale using electronic spreadsheet, it was possible to establish loading costs curves per box per farm size, enabling to observe the different systems and its productivity. The result can be seen on Figure 2.

Thinking of alternatives to avoid trucks entrance into crops' interlines, Figure 3 was made, where such systems curves were excluded, making it easier to visualize the others (S2, S4, S7 and S8). Was left as reference S1, since it is the most common and known.

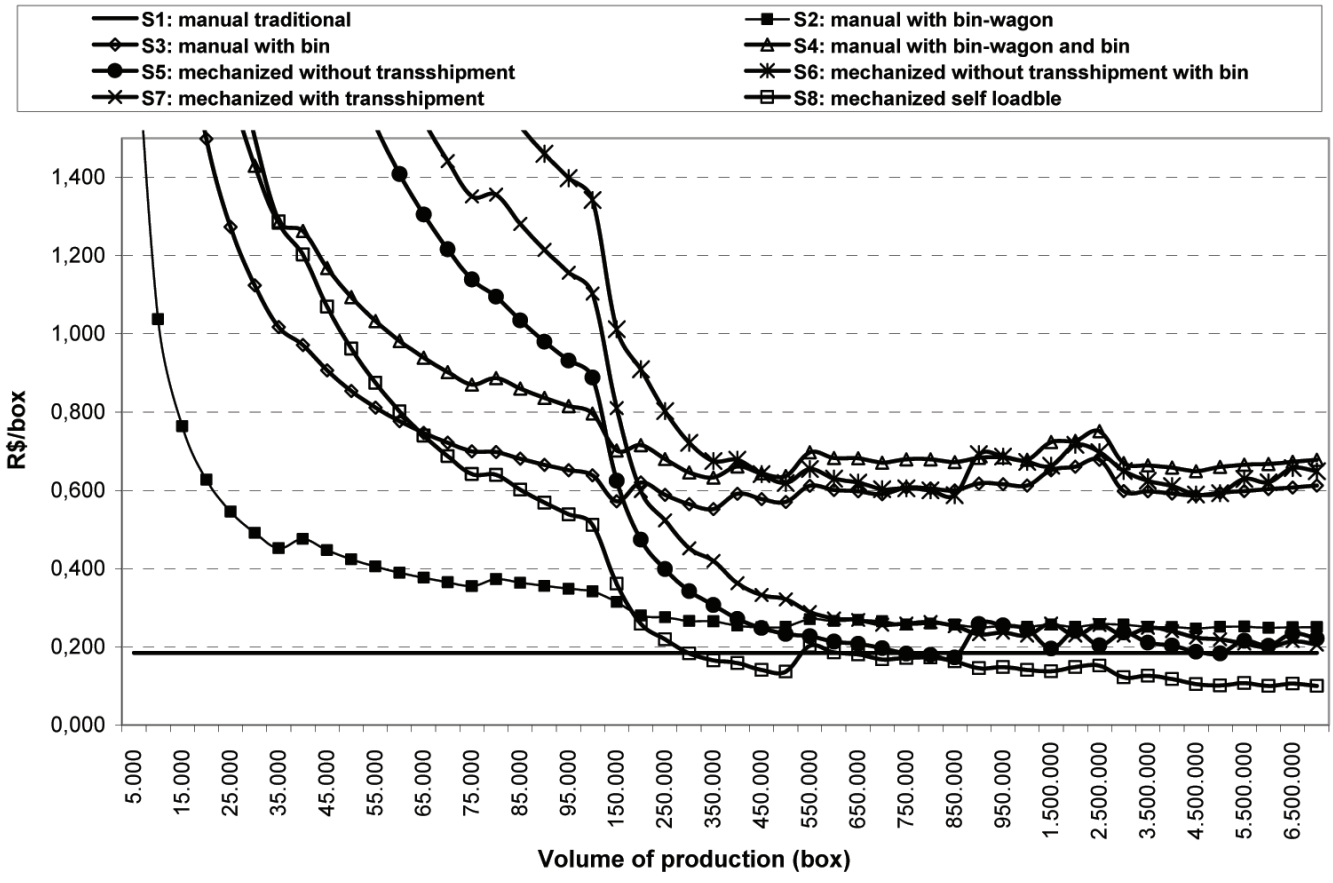

Figure 2. Curves with loading systems costs (represented by S1,..., S8), per production scale (a box contains 40.8 kg of citrus fruit)

Table 2. Citrus loading systems summary description (identified by S1,...,S8)

System 1 (S1)	System 2 (S2)	System 3 (S3)	System 4 (S4)	System 5 (S5)	System 6 (S6)	System 7 (S7)	System 8 (S8)
(manual traditional)	(manual with the help of a wagon)	(manual with bin in the farm)	(manual with the help of a wagon and with bin in the farm)	(mechanized without transshipment)	(mechanized without transshipment with bin in the farm)	(mechanized with transshipment)	(mechanized with self loadable transshipment)
Satchel	Satchel	Satchel	Satchel	Satchel	Satchel	Satchel	Satchel
Wagon	Bin- wagon	Wagon	Bin- wagon	Bag	Bag	Bag	Bag
	Wagon	Bin in the farm	Wagon	Wagon	Wagon	Transshipment	Self loadable transshipment
			Bin in the farm		Bin in the farm	Wagon	Wagon

Table 3. Number of bins, cells, people and necessary shifts, according to the size of the farm (a box contains 40.8 kg of citrus fruit)

	Farms' production (boxes)			**Nº of bins**	**Nº of cells /bin**	**Nº of workers necessary to operate 1 bin**	**Nº of shifts**	**Nº of necessary people for operation with all bins**
from	5,000	to	150,000	1	2	2	1	2
from	150,000	to	350,000	1	4	2	1	2
from	350,000	to	500,000	1	6	2	1	2
from	500,000	to	700,000	1	8	4	1	4
from	700,000	to	850,000	1	10	4	1	4
from	850,000	to	1,000,000	1	12	4	1	4
from	1,000,000	to	1,500,000	1	20	8	1	8
from	1,500,000	to	2,000,000	1	24	8	1	8
from	2,000,000	to	2,500,000	1	30	8	1	8
from	2,500,000	to	3,000,000	2	18	8	2	16
from	3,000,000	to	4,500,000	2	20	8	2	16
from	4,500,000	to	5,000,000	2	22	8	2	16
from	5,000,000	to	5,500,000	2	24	8	2	16
from	5,500,000	to	6,000,000	2	26	8	2	16
from	6,000,000	to	6,500,000	2	28	8	2	16
from	6,500,000	to	7,000,000	2	30	8	2	16

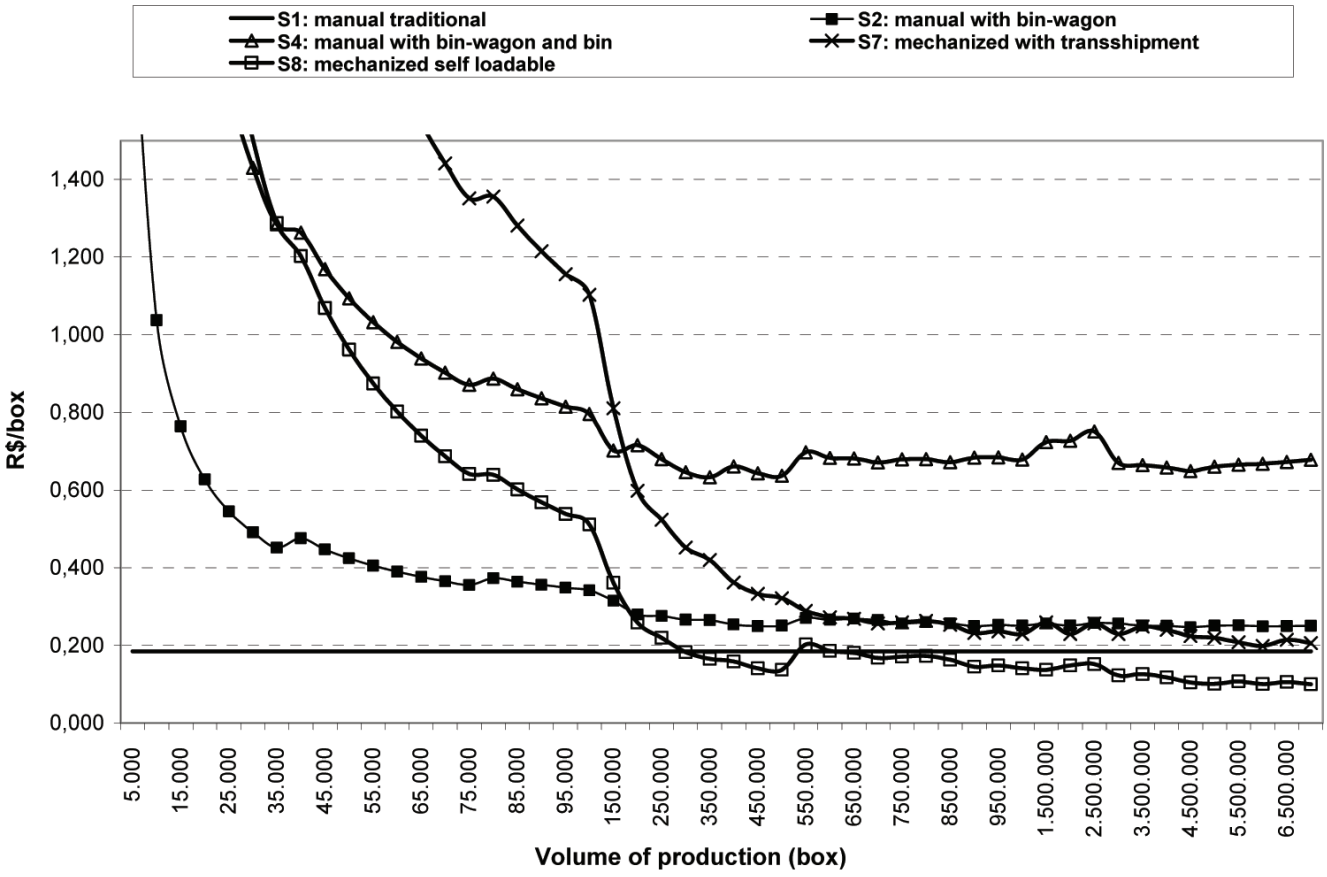

Figure 3. Curves with the costs of the selected less sanitary risk loading systems and manual loading system (represented by S1,..., S8; a box contains 40.8 kg of citrus fruit

CONCLUSIONS

It is possible to notice a great variety of orange loading systems, as each one of them have their own characteristics, fitting in farm's peculiarity and needs. All options that involve some kind of mechanization become more complex, requiring not only active investments, but also a more efficient equipment management and maintenance.

The loading mechanization system in Brazil is intimately related to bigger producers, which have as outstanding characteristics and the possibility to use economies scale, information and technology access facility. It is possible to notice that most of the big and medial producers have some mechanical equipment in their loading system, yet the decision to which method should be used is taken by empiricism, allied to previous experiences using these equipments in the farm. Now, with small producers, manual loading system is almost a rule, as this is the simplest one among all the options.

Big differences among the systems are the possibility of isolating vehicles that go around the orchard, reducing phyfitosanitary risks, mainly citrus canker. Another reason for these differences in the dissociation of loading to the harvesting groups, consequently reducing fruits offer gap from the farms to the industries.

Regarding manpower used in the harvest (which is connected with the loading, in most farms), it is a unionized category, and obey strictly its timetables and shifts. Usually the shifts go from 7 or 8 am until 4 or 5 pm, during the week; and from 7 or 8 am until 11 am or 12 pm on Saturdays. There is a great difficulty in this sector regarding this timetable, which narrows the orange offer to transportation system (in cases where loading depends on harvesting team). There are

also difficulties on Sunday journeys or shift extension. The importance of this extension on harvesting period to improve the efficiency of the harvest logistics was also evidenced by Gameiro et al. (2008) in tomato processing case.

It was observed some loading systems grouping up, in a way that the bin use alternatives formed a group with higher cost per harvested box; and the others, even the highly mechanized ones, in another group, with cost per harvested box considerably smaller. It suggested analyzing the possibility of prorating this cost increment for the systems using bin to production costs, although can be rewarded for its orchards with less infestations risk.

Thinking about sanitary security and analyzing the systems that present less contamination risks (S2, S4, S7 and S8), avoiding the truck entrance in the orchard's interlines; it is noticeable that the best option is S2 to produce levels around 150 thousand boxes . Up to this production level, S8 comes as an alternative for scale gains that already have become meaningful, making up for the investment in machines. S7 also becomes interesting for production level above 550 thousand boxes.

It is important to highlight that each system has its own working time and that S2 although is the most economic, loses its efficiency (loaded vehicles/day. equipment), making faster systems (S5) become more interesting, from the operational point of view.

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