Recovering logging residue: experiences from the Italian Eastern Alps

Raffaele Spinelli, Carla Nati, Natascia Magagnotti

Abstract – Nacrtak

Conducted within the scope of a larger Italian project, the study analyzes three recovery alternatives for logging residue and identifies the conditions that make one preferable to the others. To the purpose, the authors used spreadsheet models based on experiments, which return the delivered cost of biomass as a function of working conditions and costing assumptions. Chipping, bundling and transporting loose uncomminuted residue are all viable options, and they are indeed applied on a commercial scale in several Countries, including Italy. Transporting loose uncomminuted residue is the simplest method, which avoids investing in costly equipment. However, this system is constrained by the difficulty of fully exploiting vehicle payload: it is not suitable to the handling of fine slash, and is preferable only over short hauling distances. Chipping at the landing is technically the most effective method, but it requires close co-ordination of the transportation fleet. If truck delays exceed 40 minutes per load, then bundling becomes a better choice.

Keywords: logging residue, chipping, bundling, loose transport, delivered costs

1. Introduction – *Uvod*

In Italy, the rapid development of the bioenergy sector has boosted the biomass market: prices have increased very fast, encouraging better recovery of the existing resources and increasing imports of waste wood from neighbouring Countries. Logging residue represents an important wood source that can be exploited for energy purposes: hence the interest for new technologies that can reduce the cost of recovery and increase the share of logging residue within economic reach. There is a general interest to streamline the recovery of logging residue, which demands specific knowledge. This is particularly important for the Alps and temperate Europe in general, since much of the knowledge currently available has been generated in the Nordic Countries, under very different work conditions (Cuchet et al. 2004).

Logging residue originates from tree processing into traditional assortments, such as sawlogs and pulpwood. Processing can be conducted at the stump or at the landing, if whole trees are extracted. The latter case offers the advantage of concentrating residue, thus making recovery easier. On the other hand, residue left at the stump can always be collected and forwarded to a landing after processing. If terrain is too steep or too soft for heavy machine traffic, then the residue must always be made available at a landing – regardless of where processing takes place. The study considers residue already available at a landing – whether because trees have been processed there, or because the residue has been forwarded after processing in the stand. Under such conditions, recovery can be conducted according to one of the following three systems:

⇒ 1 – chipping at landing (Fig.1) and transporting the chips to the plant (Spinelli and Hartsough 2001);

⇒ 2 – bundling at the landing (Fig. 2), transporting the bundles (Andersson 1999) to the plant and chipping them there just before consumption;

⇒ 3 – transporting loose uncomminuted residue (Fig. 3) to the plant and chipping it there just before consumption (Ranta and Rinne 2006).

The goal of this study is to analyze these three recovery alternatives and to identify the conditions that make one preferable to the others. This way,

Fig. 1 Chipping residue at landing
Slika 1. *Iveranje na pomoćnom stovarištu*

Fig. 2 Bundling at landing
Slika 2. *Izradba svežnjeva na pomoćnom stovarištu*

managers can decide what harvesting method is best applied under their own specific work conditions. In particular, the study aims at providing: a) a break-even transport distance beyond which transporting loose uncomminuted slash becomes more expensive than transporting chips or bundles and b)

Fig. 3 Loading uncomminuted tops
Slika 3. *Utovar neusitnjenih ovršina*

the amount of interaction delay that can be accepted in chipping operations before bundling becomes a less expensive option.

2. Reseach Approach – *Istraživački pristup*

Data used for the comparison refer to a *Jenz HEM 560D* truck-mounted chipper, equipped with a 335 kW independent engine and a hydraulic loader for chipper feeding, and to a *Timberjack 1490D* truck-mounted slash bundler, also equipped with a hydraulic feeding loader. As to the third option – i.e. the transportation of loose uncomminuted residue, the model refers to a truck-and-trailer unit with special enlarged load bays and hydraulic loader. All the three operations were studied in detail, accurately measuring work time, delay time, delivered tonnage and transportation distance (Spinelli et al. 2006a). Since the goal of the study is to know when one of the three systems is preferable to the others, the three systems have been modelled through statistical analyses (SAS 1999), and the models have been used to conduct a simulation aimed at comparing system performance under varying work conditions.

Before analysing the results of this simulation – however – it is best to set some reference points, in order to better understand the different processes and to avoid errors in the interpretation and application of the results.

⇒ 1 – transporting bundles or loose uncomminuted slash all the way to the plant is only advisable when the plant is equipped with a high-output stationary chipper (Fig.4). Using such machine results in a dramatic reduction of chipping cost, which partly offsets the higher cost of transporting loose residue or the additional cost of bundling (Spinelli and Magagnotti 2005);

⇒ 2 – transporting loose uncomminuted residue has already been applied with some success both in Austria and in Finland (Ranta and Rinne 2006). In Italy this system is used on a commercial scale by some contractors in the Italian Northeast (Spinelli et al. 2006 b). However, the procedure can only be applied to an appropriate mix of tops, discarded logs and fine slash: it is unlikely that it can give favourable results when used for fine slash only, which aggravates the main drawback of loose slash transportation – i.e. the very low bulk density and the consequent difficulty of fully exploiting vehicle payload (Rawlings et al. 2004). For the same reasons, the profitability of transporting loose slash drops very quickly with transportation distance, and the system is only suitable to short hauls. In general, the advantage of transporting loose residue is the dramatic reduction of the investments in dedicated machinery – such as a mobile chipper or a bundler, which may cost between 300,000 and 400,000 €;

⇒ 3 – bundling has two main limits: first of all, it represents an additional processing step, and secondly it runs at a much slower pace compared to chipping. In fact, a bundler hourly cost is almost the same of a chipper with almost twice its productivity. The main advantage of bundling is logistics: while chippers generally need a truck by the side to receive the chips they expel from their spouts, bundlers are completely independent, as they can stack the bundles on the ground for later collection by transportation units (Johansson et al. 2006). This prevents any problems with co-ordinating the chipper and the truck fleet, which may cause considerable delays – possibly offsetting the productivity edge of the chipper. Joint chipper and truck operation also requires larger landings, which can accommodate a chipper and a truck at the same time. On the contrary, a bundler can be used on smaller landings, since the transport vehicle can move in after the bundler has finished with its job. Therefore, comparison between the chipper and the bundler boils down to identifying the »disorganization threshold« acceptable for the chipping operation, before its productive edge is totally eroded and bundling becomes a cheaper option.

3. Results – *Rezultati*

Simulation was based on the experimental data shown in Tables 1 and 2, respectively for slash processing (chipping or bundling) and transport: these data were recorded on well-organized operations, as shown by the very limited incidence of delays. Experimental data were compatible with the figures obtained by other authors for similar machines: in particular, the performance recorded for the truck-mounted bundler in Italy was very similar to that obtained with the same machine in other studies conducted in Austria (Kanzian 2005) and Germany (Wittkopf 2004). The tables refer both time consumption and machine productivity to the oven-dry tonne (odt) in order to provide unambiguous reference.

As to chipping at the plant, data collection highlighted the high productivity of stationary chippers, which reached 16.7 oven-dry tonnes/hour with bundles and 14.4 oven-dry tonnes/hour with slash.

Fig. 4 Stationary chipper
Slika 4. *Stacionirani iverač*

Table 1 Productivity of chipping and bundling
Tablica 1. *Proizvodnost iveranja i izradbe svežnjeva*

Process Radni postupak	Chipping *Iveranje*	Bundling *Izradba svežnjeva*
Work, min/odt *Rad*, min/odt	7.5	10.0
Other, min/odt *Ostalo*, min/odt	0.5	2.4
Delay, min/odt *Prekid*, min/odt	1.0	0.9
Delay, % of total time *Prekid, % od ukupnoga vremena*	10.8	6.8
Productivity, odt/h *Proizvodnost*, odt/h	6.7	4.5

odt – oven-dry tonne – *masa suhe tvari, t* Source – *Izvor*: Spinelli et al. (2006)

Operation cost was estimated with the usual accounting methods adapted to forestry (Miyata 1980). We assumed an initial investment of 320,000 € for the truck-mounted chipper, 400,000 € for the truck-mounted bundler, 110,000 € for each truck and 130,000 € for each truck-and-trailer unit. These amounts were depreciated over 8 years to a salvage value of 20%. The annual utilization was set to 1000 hours, assuming a professional use. Transportation units make exception, as they are generally used more intensively: therefore we assumed a depreciation over 5 years and an annual utilization of 1800 hours. Labour cost was set to 18 €/hour, interest rate to 4% and fuel cost to 1.1 €/litre. The raw costs thus obtained were increased by 25%, to account for profit and overheads. The hourly operating costs are then 165 € for the mobile chipper, 159 € for the bundler, 59 € for the truck and 70 € for the truck and trailer combination. When loose uncomminuted slash is transported, we have included the cost of a second operator to assist the loading, as tops often need some trimming: this work could be done by the loader operator if the grapple was equipped with a hydraulic saw – however, no such arrangement was observed during our studies and we preferred to avoid extrapolation of data. The cost of the loading assistant was estimated to 18 €/hour and charged on the loading time only, not on the whole cycle. The operating cost of the stationary chipper was calculated on different assumptions, closer to the economical environment of large industry such as: utilization of 4800 hours/year, depreciation on 8 years and electricity cost of 0.08 €/kWh. Results were checked with the assistance of the plant managers and indicate a chipper cost of 130 €/hour.

Table 2 Productivity of transportation
Tablica 2. *Proizvodnost prijevoza*

	Product – *Proizvod*		
	Chips *Iverje*	Bundles Svežnjevi	Slash *Granjevina*
Truck – *Kamion*			
Load, odt *Tovar*, odt	6.3	5.9	3.5
Travel on forest road, km/h *Vožnja po šumskoj cesti*, km/h	14	14	14
Travel on country road, km/h *Vožnja po lokalnoj cesti*, km/h	30	30	30
Travel on state road, km/h *Vožnja po državnoj cesti*, km/h	52	52	52
Load, min/trip *Utovar*, min/tura	50.3	20.7	17
Weight and Unload, min/trip *Vaganje i istovar*, min/tura	8.4	21.6	10.8
Delay, min/trip *Prekid*, min/tura	8.1	8.1	8.1
Truck-and-trailer – *Kamionski skup*			
Load, odt *Tovar*, odt	16.0	15.0	9.6
Travel on forest road, km/h *Vožnja po šumskoj cesti*, km/h	14	14	14
Travel on country road, km/h *Vožnja po lokalnoj cesti*, km/h	21	21	21
Travel on State road, km/h *Vožnja po državnoj cesti*, km/h	50	50	50
Load, min/trip *Utovar*, min/tura	127.7	52.6	117.0
Weight and Unload, min/trip *Vaganje i istovar*, min/tura	21.0	48.3	18.7
Delay, min/trip *Prekid*, min/tura	10.1	10.1	10.1

Source – *Izvor*: Spinelli et al. (2006)

Data shown above were assembled in a worksheet and used to calculate:

⇒ the maximum distance within which transporting loose uncomminuted slash is less expensive than transporting chips or bundles;

⇒ the amount of chipping delay that can be accepted before bundling becomes a less expensive option.

These simulations were conducted for two different cases, and namely: 1) landing size and road standard allow using truck-and-trailer units for trans-

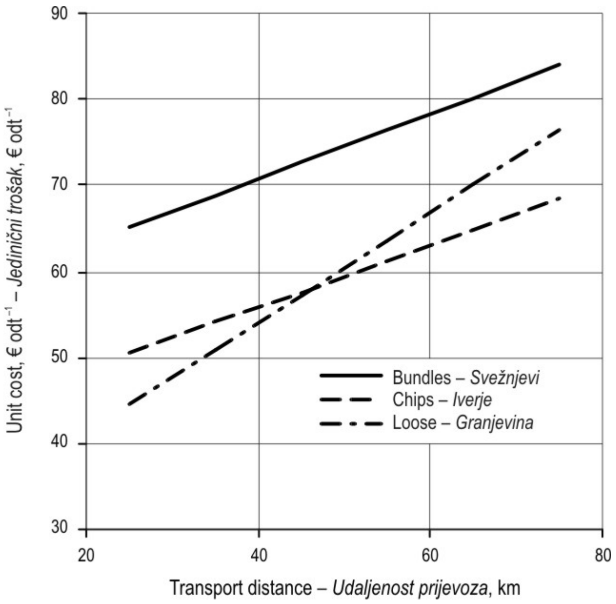

Fig. 5 Relationship between delivered cost and transport distance (truck option)

Slika 5. *Ovisnost troškova dobave o udaljenosti prijevoza kamionom*

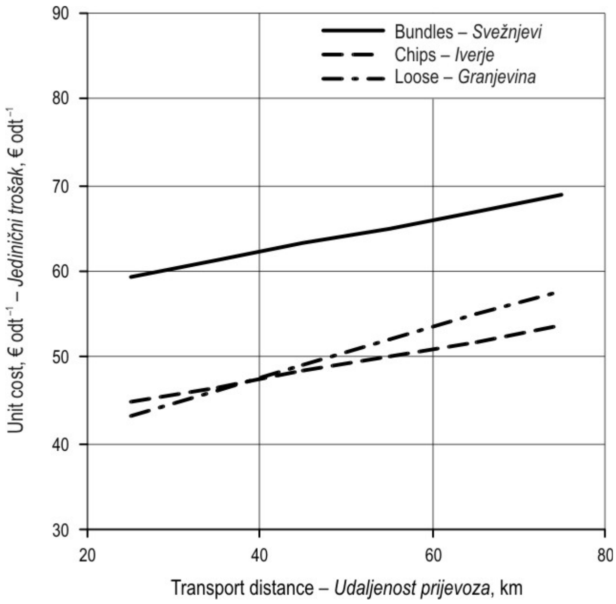

Fig. 6 Relationship between delivered cost and transport distance (truck-trailer option)

Slika 6. *Ovisnost troškova dobave o udaljenosti prijevoza kamionskim skupom*

portation, and 2) landing size and/or road standards force resorting to trucks for transportation.

Figures 5 and 6 show the relationship between delivered cost and transportation distance for the three alternatives: figure 5 refers to truck transportation, whereas figure 6 is based on the use of truck-and-trailer units. In both cases, we assumed that the operations are well organized and that the chipper normally waits 5 minutes between the departure of a transport unit and the arrival of the next one.

In both cases, bundling proves to be the least efficient option: on the contrary, transporting loose uncomminuted residue emerges as the cheapest alternative, when transportation distance does not exceed 40 km. Of course, this is only true for relatively large-sized slash: it is very difficult to assemble a significant load with fine slash, after taking away the tops and all the stemwood with a diameter above 10–12 cm. The operations observed were indeed conducted on residue obtained after delimbing trees and topping them to a diameter of 18–20 cm.

Although the chipping chain is much cheaper than the bundling chain, the former is very sensitive to organizational problems: a chipper can work effectively only if a truck is placed by its side to receive the chips, and it is not always easy to guarantee a good co-ordination of the chipper and the truck fleet. Therefore, chipper work can be slowed down by recurring waiting delays, which can be considered normal and acceptable if their incidence is contained

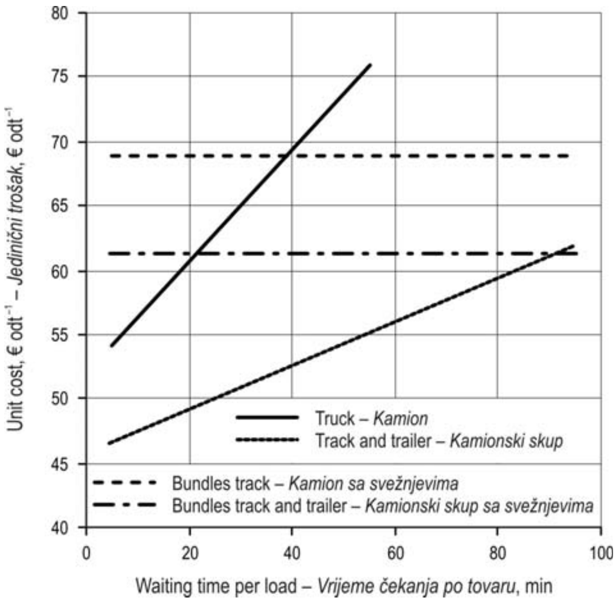

Fig. 7 Delivered cost of chips as a function of chipper waiting time between loads

Slika 7. *Ovisnost troškova dobave o vremenu prekida rada iverača – čekanje između tovara*

within certain limits. In our previous simulation runs, we have assumed an average delay between trucks of 5 minutes, which is certainly acceptable: as delays grow increasingly long, chipping cost becomes higher, and at a certain point it will reach the same value as bundling cost. Beyond that figure, bundling becomes a preferable option. Figure 7 shows the results of a simulation conducted for increasing chipper waiting time, assuming a transportation distance of 35 km, 2 of which on forest roads, 10 on country roads and the remaining 13 on state roads.

If transportation is performed by trucks, chipping is preferable to bundling until the average waiting time between the departure of a truck and the arrival of the next one is below 40 minutes (Fig. 7). When truck-and-trailer units are used, the chipper can afford an average waiting delay of almost an hour and a half, before bundling becomes a better alternative. Finally, there is a third possibility, namely that the landing is too narrow for accommodating a chipper and a truck-and-trailer unit at the same time, but it can indeed accept the truck-and-trailer if the chipper was not there: in such instance, bundling would allow upgrading to the more efficient transportation unit, whereas chipping forces resorting to simpler, less efficient trucks. If this is the case, chipping is preferable only if waiting delays can be contained within the average value of 20 minutes per load (Fig. 7).

4. Conclusions – *Zaključak*

Chipping, bundling and transporting loose uncomminuted residue are all viable options, and they are indeed applied on a commercial scale in several Countries, including Italy. Each alternative has its advantages and drawbacks, which must be carefully evaluated in order to make the choice that is most appropriate to the specific situation.

Transporting loose uncomminuted residue is the simplest method, which avoids investing in costly equipment. However, this system is constrained by the difficulty of fully exploiting vehicle payload and it is not suitable to the handling of fine slash.

Chipping at the landing is technically the most effective method, but it requires close co-ordination of the transportation fleet. The number of units assigned to the operation must reflect both chipper capacity and transportation distance: excessive waiting erodes the productive edge of chipping at landing, and favours the other two methods.

Bundling represent an additional process and therefore increases the total cost of recovery: however, it has the advantage of independent operation and prevents much of the organizational problems related to chipping at forest landings. If local logging companies are not organised well enough to guarantee close operational co-ordination, bundling becomes a better alternative – especially if the slash is fine, which excludes transportation of loose uncomminuted residue.

The simulations conducted here show that bundling is preferable to chipping when the average waiting time for the chipper reaches 40 minutes per truck, or a hour and a half per truck-and-trailer unit. If bundling also allows transportation on a truck-and-trailer unit rather than on a truck, chipping at the landing must be preferred only if the average waiting time per truck is not longer than 20 minutes.

Of course, such results depend on the specific costing assumptions previously described: different conclusions could be reached under other assumptions, such as a less intensive utilization of the machinery, the release of public subsidies or the availability of labour at marginal costs. For this reason, readers are encouraged to request and use the above-mentioned free worksheet to calculate a personalised recovery cost and to compare options under user-specified conditions.

Acknowledgements – *Zahvala*

Since 2003, CNR has initiated a new project on the cost-effective production of forest chips in the Alpine forests of Northeastern Italy. The project has received the sponsorship of 14 different organizations, including the Regional Forest Services of Trentino, Veneto and Friuli Venezia Giulia, as well as the main forest owners' Associations of the area. Twenty field tests were conducted on a variety of stands and conditions, leading to the production of several spreadsheet models. Overall results have been summarized in a book of »Guidelines for the development of forest chip supply chains«, also available in English. The electronic version of the book can be requested to the corresponding Author at: spinelli@ivalsa.cnr.it

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Sažetak

Iskorištavanje drvnoga ostatka pri sječi i izradbi – iskustvo iz talijanskih istočnih Alpa

Ubrzani je razvoj uporabe obnovljivih izvora energije u Italiji utjecao na tržište proizvoda biomase povećavajući cijene proizvoda, iskoristivost postojećih izvora biomase te uvoza drvnih ostataka iz susjednih zemalja.

Drvni ostatak nastaje kao nusproizvod sječe i izradbe, a predstavlja važan izvor drvne sirovine koji se može iskoristiti u energetske svrhe. Primjenom sortimentne metode izradba se obavlja u sječini kod panja te se drvni ostatak treba skupiti i privući na pomoćno stovarište. Kod stablovne metode izradba se obavlja na pomoćnom stovarištu pri čemu se drvni ostatak gomila na jednom mjestu, što olakšava njegovo iskorištavanje.

U radu se pretpostavlja da je drvni ostatak dostupan na pomoćnom stovarištu bilo zbog izvođenja izradbe stabala na stovarištu ili zbog privlačenja drvnih ostataka nakon izradbe u sječini. Pri tome će se razmatrati tri postupka pri iskorištavanju drvnoga ostatka:

⇒ *iveranje na pomoćnom stovarištu i prijevoz iverja do energane*

⇒ *izradba svežnjeva od drvnoga ostatka na pomoćnom stovarištu te prijevoz svežnjeva i njihovo iveranje u energani*

⇒ *prijevoz neusitnjenoga drvnoga ostataka (granjevine) i iveranje u energani.*

Cilj je rada da se utvrdi udaljenost pri kojoj je prijevoz neusitnjenoga drvnoga ostatka skuplji od prijevoza iverja ili svežnjeva te udio prekida rada do kojega je iveranje troškovno prihvatljivije od izradbe svežnjeva.

Za usporedbu su korištena ova sredstva:

⇒ *na kamionu postavljen iverač Jenz HEM 560D snage motora 335 kW, opremljen hidrauličnom dizalicom*

⇒ *na kamionu postavljen bandler Timberjack 1490D, opremljen hidrauličnom dizalicom*

⇒ *kamionski skup (kamion s prikolicom) opremljen hidrauličnom dizalicom te povećanim tovarnim prostorom za prijevoz neusitnjenoga drvnoga ostatka.*

Istraživanje različitih načina iskorištavanja drvnoga ostatka provedeno je studijem rada i vremena, mjerenjem isporučene težine drvnoga ostatka te prijeđenim udaljenostima prijevoza. Svi su postupci modelirani statističkom raščlambom te uspoređeni radi određivanja najisplativijega postupka pri različitim uvjetima rada. Pri tome je potrebno naglasiti određene značajke tih postupaka. Za prijevoz svežnjeva i neusitnjenoga drvnoga ostatka energana mora biti opremljena visoko učinkovitim stacioniranim iveračem. Prijevoz neuistnjenoga drvnoga ostatka može se primijeniti jedino u slučaju velikoga udjela sitne granjevine koja omogućuje veću gustoću tovara, tj. bolju iskorištenost nosivosti vozila. Izradba je svežnjeva dodatni postupak u procesu proizvodnje, a satni trošak bandlera jednak je trošku iverača s dvostruko većom proizvodnosti. No, rad iverača zahtijeva kamion na mjestu *rada za prihvat iverja i time prostrana stovarišta. Također je potrebna dobra organizacija rada iverača i kamiona za prijevoz iverja kako bi se izbjegli dulji prekidi rada. Bandler je neovisan o kamionu te može slagati svežnjeve u složajeve čime se olakšava i ubrzava kamionski utovar.*

Uporedba postupaka pri iskorištavanju drvnoga ostatka provedena je na podacima prikazanima u tablicama 1 i 2 dobivenima prijašnjim istraživanjima. Učinak stacioniranoga iverača u energani iznosi 16,7 tona suhe tvari na sat pri iveranju svežnjeva, odnosno 14,4 tone suhe tvari na sat pri iveranju granjevine.

Za izračun troškova rada pretpostavljeni su i određeni ovi parametri: početna ulaganja od 320 000 € za iverač, 400 000 € za bandler, 110 000 € za svaki kamion, 130 000 € za kamionski skup, vrijeme amortizacije iverača i bandlera 8 godina uz godišnju iskoristivost od 1000 pogonskih sati, vrijeme amortizacije prijevoznih sredstava 5 godina uz godišnju iskoristivost od 1800 pogonskih sati, trošak radnika 18 €/h, kamatna stopa 4 %, trošak goriva 1,1 €/L. Izračunati trošak rada iznosi 165 €/h za iverač, 159 €/h za bandler, 59 €/h za kamion i 70 €/h za kamionski skup. Za stacionirani iverač u energani trošak rada iznosi 130 €/h uz određeno vrijeme amortizacije od 8 godina, godišnju iskoristivost od 4800 pogonskih sati te trošak električne energije 0,08 €/kWh.

Na slikama 5 i 6 prikazane su ovisnosti jediničnih troškova o udaljenosti prijevoza kamionom i kamionskim skupom za sve tri inačice. U oba slučaja pretpostavljen je prekid rada iverača na stovarištu od 5 minuta zbog čekanja prijevoznoga sredstva. Izradba i prijevoz svežnjeva pokazuju se najskupljom opcijom, dok je prijevoz neuistnjenoga drvnoga ostatka najisplativiji na udaljenosti do 40 km.

Slika 7 prikazuje rezultate ovisnosti jediničnih troškova o povećanju prekida rada iverača zbog čekanja prijevoznoga sredstva pri udaljenosti od 35 km, od toga 2 km na šumskoj cesti, 10 km na lokalnoj cesti i 13 km na državnoj cesti.

Kod prijevoza kamionima iveranje je povoljnije od izradbe svežnjeva ako su prekidi rada iverača manji od 40 minuta. Kod prijevoza kamionskim skupovima tek kad su prekidi rada iverača veći od sat i 30 minuta, izradba svežnjeva postaje troškovno povoljnija. U slučaju manje prostranoga stovarišta na kojem se ne može uz iverač smjestiti kamionski skup već jedino kamion, izradba je svežnjeva troškovno isplativija kada prekidi rada iverača zbog čekanja kamiona premaše 20 minuta po tovaru.

Iz rezultata se zaključuje da je prijevoz neusitnjenoga drvnoga ostatka najjednostavnija metoda kojom se izbjegava nabava skupih sredstva, ali se javlja problem nedovoljne nosive iskoristivosti prijevoznoga sredstva. Iveranje je na pomoćnom stovarištu najučinkovitija metoda, ali zahtijeva vrlo dobru organizaciju prijevoznih sredstava. Povećanjem prekida rada iverača zbog čekanja prijevoznoga sredstva smanjuje se proizvodnost iverača te se pridonosi opravdanosti primjene drugih dvaju postupaka. Izradba svežnjeva povećava ukupni trošak proizvodnoga procesa, ali je tehnološko rješenje neovisno o organizacijskim problemima.

Ključne riječi: šumski ostatak, iveranje, izradba svežnjeva, prijevoz granjevine, troškovi dobave

Authors' address – *Adresa autorâ*:

Raffaele Spinelli, PhD
e-mail: spinelli@ivalsa.cnr.it
Carla Nati, PhD.
e-mail: nati@ivalsa.cnr.it
Natascia Magagnotti, BSc.
e-mail: magagnoti@ivalsa.cnr.it
CNR/IVALSA
Via Madonna del Piano – Palazzo F
I-50019 Sesto Fiorentino (FI)
ITALY

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