PRODUCTION ANALYSIS OF TWO TREE-BUCKING AND PRODUCT-SORTING METHODS FOR HARDWOODS[1]

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ABSTRACT

This paper documents the results of a study to determine the cost and productivity of two tree-bucking and product-sorting methods used by West Virginia loggers harvesting three to four types of roundwood products. The methods include manual chain saw bucking and bucking with a hydraulically powered chain saw slasher. Results show that chain saw bucking of trees averaging 53 ft^3 produced 2,155 ft^3/productive hour. This compares to 1,109 ft^3/productive hour for mechanized bucking of trees averaging 33 ft^3. Utilization levels below 50 percent for each method indicate that both were capable of greater production with increased felling and skidding production, and that added product sorting would not limit system output or increase harvesting cost. Results also include regression equations for estimating bucking and sorting time per skidder turn as a function of turn and tree attributes. The results should be useful to logging planners and managers considering multiproduct harvests.

INTRODUCTION

Multiproduct timber harvesting affords loggers and landowners the opportunity to increase harvesting revenue and improve wood utilization. Because harvesting equipment costs have increased more than wood prices (Cubbage et al. 1988), it is essential that loggers either increase productivity or increase unit revenue by separating and sorting additional primary products from trees harvested. Dennis and Remington (1987) reported that loggers are resorting to integrated harvesting to improve profits. Accordingly, the tree bucking and product sorting required to harvest multiple products can be an important component of the stump-to-mill harvesting process.

This report documents the results from a production study of two tree-bucking and product-sorting methods commonly used on ground-based eastern hardwood harvesting operations. These included manual chain saw bucking and bucking with a hydraulically powered chain saw slasher. The objective of this study was to determine productivity and costs, and to develop production-rate estimators for both bucking and sorting methods. The two operations studied were located in northeastern West Virginia. Although factory-grade sawlogs were the primary product, the loggers separated and sorted three to four different primary products.

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[1] Presented at the Southern Regional Council on Forest Engineering Meeting, Auburn University, AL, May 3-4, 1989.

LOGGING OPERATIONS

Chain Saw Bucking

Trees harvested at the chain saw-bucking site were predominantly northern hardwoods; black cherry, maple, ash, and basswood. Rubber-tired skidders decked bole-length stems alongside the knuckleboom loader located at the landing. The bucker used an 8-foot measuring stick and hatchet to measure and mark bucking points on all stems in a skidder turn. The bucker then proceeded from one end of the turn to the other, bucking all stems at the points marked. The 20,000-pound-capacity loader was not an integral part of the bucking process. The loader often sorted, decked, and loaded logs while the current turn of logs was being bucked. To accommodate two to three rubber-tired skidders and two loaders required a landing area approximately 100 by 200 feet. However, the contractor reported using landings approximately half this size when working at other sites with only one loader and one or two skidders.

Products sorted at the chain saw bucking site included:

- Veneer logs
- Factory-grade sawlogs, scaling diameter ≥ 12 inches
- Factory-grade and low-grade sawlogs, scaling diameter 8 to 12 inches
- Pulpwood, lengths 8 to 20 feet, diameter ≥ 4 inches.

Slasher Bucking

The slasher processed a mixture of red and white oaks. The Hydro Saw-Buck model 1000[2] was powered and controlled by the loader (Fig. 1) A rubber-tired skidder decked bole-length stems at the 60- by 90-foot landing. In this operation, the loader was an integral part of the bucking process; it was used to load stems on the slasher bunk, position stems after each bucking cut, and place all bucked logs in the appropriate product decks. Most wood was hauled by a self-loading tri-axle truck. Only occasionally was the loader used to load out pulpwood.

The shop-built, 40-foot-long slasher bunk supported stems during bucking, and provided the means to measure log lengths up to 20 feet on each side of the slasher saw. The slasher operator carefully positioned all sawtimber stems to ensure correct log lengths and to minimize crook and sweep. Although two or three pulpwood stems were sometimes bucked in a single batch, the slasher was not used to process large batches of pulpwood stems into shortwood pulp as is often the application for this type of machine.

Roundwood products produced at the slasher site included:

- Factory-grade sawlogs, scaling diameter ≥ 12 inches
- Factory-grade and low-grade sawlogs, scaling diameter 8 to 12 inches
- Pulpwood, lengths 8 to 20 feet, diameter ≥ 4 inches.

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[2] The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture or the Forest Service of any product or service to the exclusion of others that may be suitable.

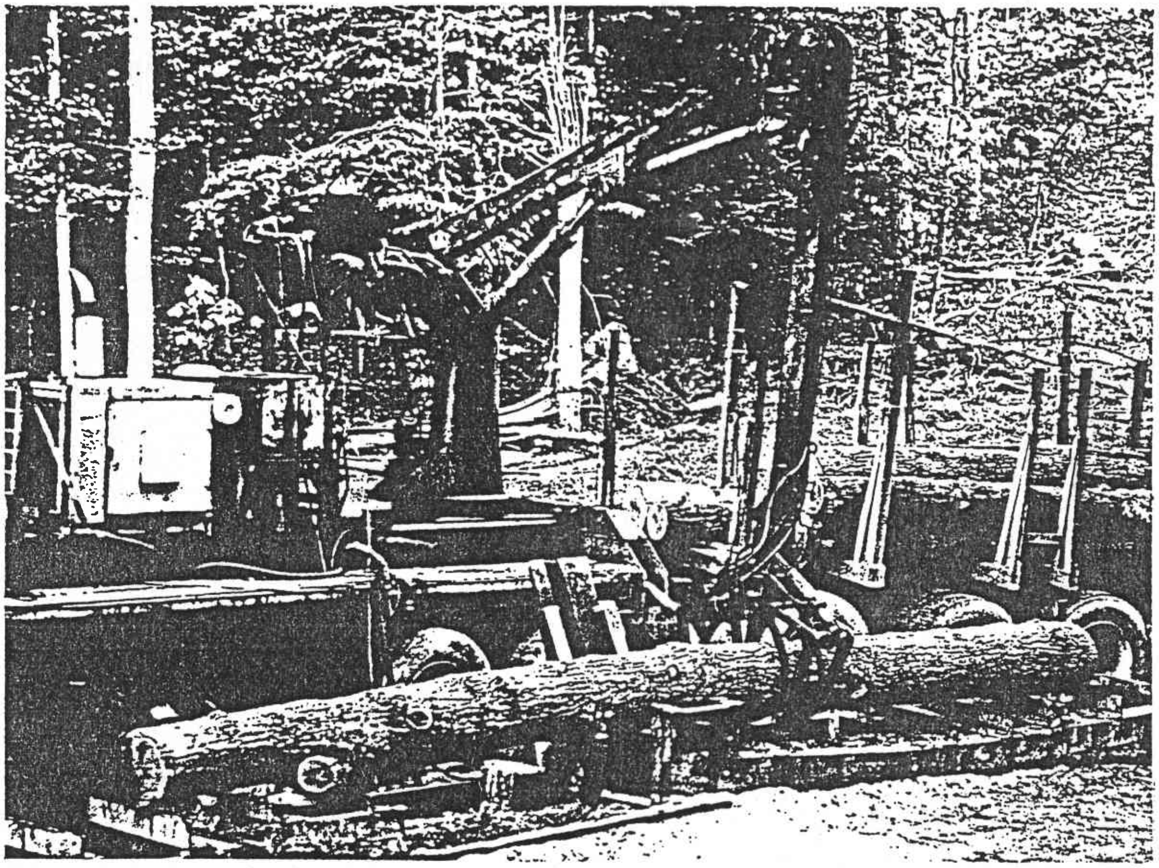

Figure 1.--Slasher powered and controlled by hydraulic loader.

STUDY METHOD

The following data were collected for each stem bucked: number of logs bucked, total stem length, small-end diameter outside bark (DOB), and large-end DOB measured above the butt swell. Gross volume was calculated using Smalian's formula. Additional stem data collected at the slasher site included numbers and lengths of sawlogs and pulpwood logs. Based on tree taper, log length, and log position in the stem, product volumes were estimated for the slasher sample.

Bucking cycle time and delay time were recorded for each stem or batch of stems processed. Chain saw bucking proceeded on a batch versus individual-tree basis, where a batch equalled a skidder turn of stems. As a result, bucking cycle time and delay time could be measured only for each skidder turn of logs. Although slasher cycle times and delay times were recorded for each stem processed, these times were consolidated by skidder turn to be consistent with the chain saw-bucking data. Chain saw-bucking cycle time includes marking and bucking. Slasher cycle time includes bucking, sorting, and decking time. Delay times included maintenance and waiting for the next turn of stems. Additional data collected at the chain saw-bucking site included loader cycle times for decking, sorting, and loading bucked logs.

RESULTS

Comparing stem dimensions between the two samples indicates that chain saw-bucked stems had the largest average butt diameter, top diameter, and length (Table 1). As a result, the gross volume of stems bucked at the chain saw site averaged 53 ft^3, versus 33 ft^3 for stems processed at the slasher site. Most of the stems processed at the slasher site were concentrated in the 10- to 40-ft^3 classes. The bulk of the chain saw-bucked stems were in the 30- to 70-ft^3 classes.

Table 1 - Attributes of stems processed at each study site

Stem attribute	Slasher[a] Mean	Slasher[a] Range	Chain saw[b] Mean	Chain saw[b] Range
Butt DOB (inches)	14.8	6-28	17.8	9-28
Top DOB (inches)	9.7	4-18	12.0	6-20
Length (feet)	34.4	12-62	40.7	8-65
Number of logs	2.7	1-5	2.8	1-7
Gross volume (ft^3) (wood and bark)	33.0	2-130	53.0	7-118

[a] N = 290.
[b] N = 390.

Table 2–Turn attributes and cycle times for slasher and chain saw bucking

Stem attribute	Slasher[a] Mean	Slasher[a] Range	Chain saw[b] Mean	Chain saw[b] Range
Number of trees	4.1	1-7	4.6	2-8
Number of logs	10.9	3-19	13.2	5-25
Volume (ft^3)	132.0	30-386	248.0	101-500
Production time (min.)	7.15	2.0-17.4	6.89	1.8-18.2
Delay time (min.)	7.94	0-33.4	7.51	0-40.0

[a] N = 71.
[b] N = 85.

With more trees per skidder turn and larger average tree volume, average turn volumes processed by chain saw bucking were nearly double those processed by the slasher–248 ft^3/turn versus 132 ft^3/turn (Table 2). Nonetheless, average productive cycle time was 6.89 min./turn for chain saw bucking and 7.15 min./turn for the slasher. Because bucking and decking were separate and parallel functions, and the sorting-decking process did not affect bucking time, chain saw-bucking cycle times include only marking and bucking. Slasher cycle times necessarily include bucking, sorting, and decking, which were serial functions in this process.

Log volume processed per productive machine hour (PMH) was calculated from the average productive cycle time and average turn volume. This rate was 2,155 ft^3/PMH for chain saw bucking and 1,109 ft^3/PMH for slasher bucking and decking. Volume processed per scheduled machine hour (SMH) was based on total time and includes productive and delay time. This rate was 1,031 ft^3/SMH for chain saw bucking and 526 ft^3/SMH for the slasher.

Utilization, or PMH/SMH, was nearly equal for the two methods--0.48 for chain saw bucking versus 0.47 for slasher bucking and decking. Most of this delay time represents waiting for the next turn of logs. The relatively low levels of utilization indicate that both processes could support added felling and skidding production, or additional production time for bucking and sorting more product types.

PRODUCTION MODELS

Cycle-time prediction models were developed through ordinary least-squares regression analysis. The objective was to develop cycle-time estimators for production and cost analysis of harvesting systems. Two regression equations were developed for each method. The "best" model for each method, equations 1 and 2 in Table 3, was developed through forward stepwise regression and selected based on the standard error of the estimate and Mallow's Cp statistic (Draper and Smith 1981). The second model developed for each method, equations 3 and 4 in Table 3, included only sets of independent variables that were significant at the 0.05 level for both bucking methods. The objective was to find a set of independent variables that worked well with both bucking methods and could be used to compare cycle time, production rates, and unit cost based on identical turn attributes.

Table 3--Regression equations and coefficients for chain saw and slasher time models. The dependent and independent variable designations for these equations are: CTS = slasher productive cycle time (min./turn). CTC = chain saw productive cycle time (min./turn). X_1 = number of logs per turn. X_2 = sawlog volume (ft^3/turn). X_3 = average stem volume (ft^3/stem). X_4 = average log volume (ft^3/log). X_5= number of stems per turn. X_6 = total length of stems (ft/turn). X_7 = total volume (ft^3/turn).

Equation	------Statistics------		
	R^2	Sy.x	F
(1) CTS = $1.202 + 0.4239X_1 + 0.0194X_2 + 0.0479X_3 - 0.1992X_4$	.95	.60	256.4
(2) CTC = $-6.0807 + 0.6878X_1 + 0.1312X_3 + 0.7176X_5 - 0.0308X_6$	.78	1.62	48.3
(3) CTS = $-0.3238 + 0.3657X_1 + 0.0254X_7$	.93	.71	349.0
(4) CTC = $0.7384 + 0.2578X_1 + 0.0134X_7$	.71	1.81	71.7

The two models sharing a common set of independent variables perform nearly as well as the "best" models (Table 3). Production rate estimates derived from equations 3 and 4 are shown in Figure 2. Estimated production rate is equal to (60/est. cycle time) x turn volume.

The results are plotted over average log volume, or X_7/X_1. These results show that chain saw-bucking production exceeds slasher production over a wide range of turn volumes and average log volumes. Production rates for both methods increase with increasing log volume. Chain saw-bucking production also increases with turn volume when holding average log volume constant, which equates to increasing the number of logs bucked per turn. Conversely, Figure 2 shows a small decrease in slasher production with increased turn volume or number of logs per turn, which may be attributed to added time required to sort through large turns to pick out pulpwood stems for batch bucking.

It is important to note that the slasher takes production one step farther than chain saw bucking to include sorting and decking as well as bucking. This explains the lower production-rate estimates for the slasher, which must deck each log before bucking the next log. Consequently, the production rates in Figure 2 do not include identical production elements. However, if the loader on the chain saw-bucking operation has the capacity to sort, deck, and load at the rates shown for chain saw bucking, then chain saw bucking, decking, and loading would likely proceed at the rate shown for bucking. The additional sorting and decking required for chain saw-bucked logs should not slow the bucking process. As mentioned previously, these are parallel operations and chain saw bucking is seldom affected by subsequent sorting and decking operations.

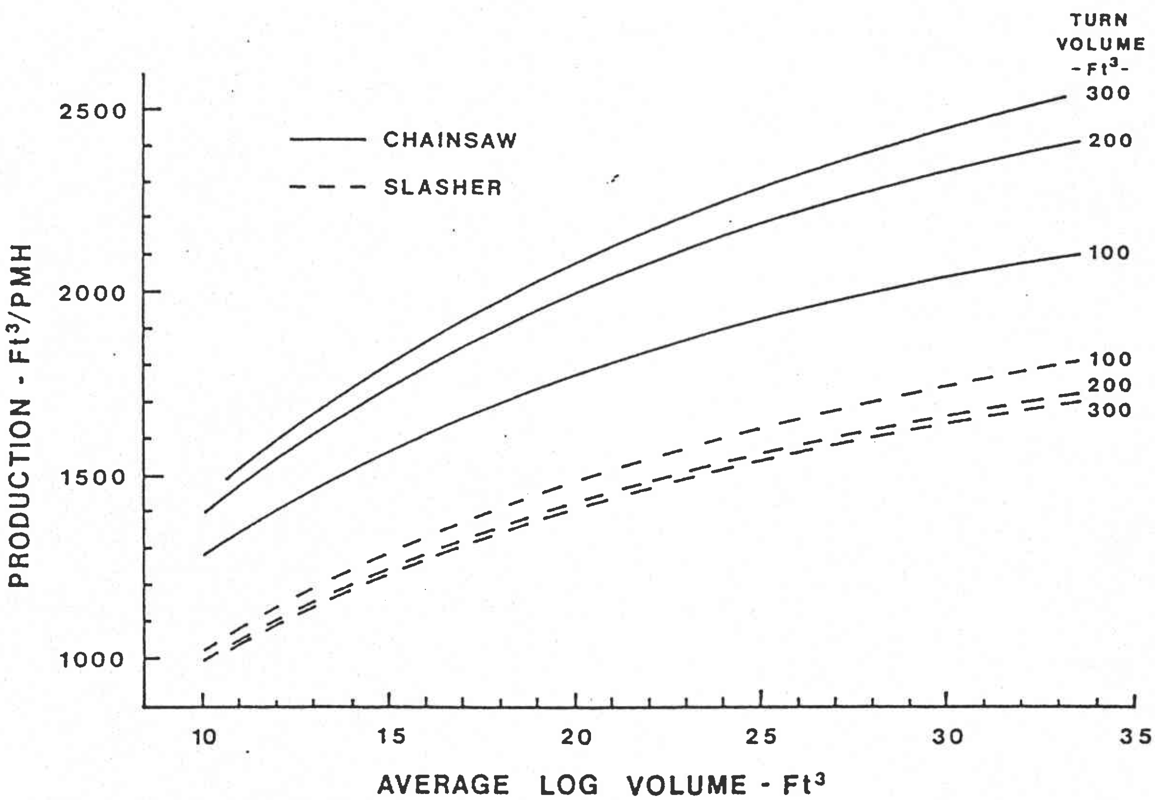

Figure 2.--Estimated production rates for chain saw bucking and mechanized bucking and decking.

COST ANALYSIS

To compare unit costs on an equivalent basis, it was necessary to add loader costs associated with sorting and decking to the cost of chain saw bucking. The results compare bucking, sorting, and decking costs. Analysis of the loader cycle times collected at the chain saw bucking site shows 449 loading cycles averaging 0.58 min./log and 340 sorting-decking cycles averaging 0.375 min./log. Approximately 75 percent of the logs bucked were decked prior to loading. The remainder were loaded directly from the pile of bucked logs. Based on the proportion of logs decked and average cycle times, approximately one-third of productive loader time per log processed was spent sorting and decking, or $(0.75)(0.375)/[(0.75)(0.375) + 0.58] = 0.33$. Accordingly, one-third of the estimated loader and loader operator costs was assigned to sorting and decking chain saw-bucked logs.

Machine rates used in the cost analysis (Table 4) are those of Dorris and Cubbage (1987). Fixed costs were adjusted to 1600 SMH/year. At the sampled production rate, chain saw bucking cost \$0.97/100 ft³. Assuming 80-percent utilization of the loader for sorting, decking, and loading, sorting and decking costs were \$0.78/100 ft³. Chain saw bucking, sorting, and decking costs totaled \$1.75/100 ft³.

Table 4--Machine rate and labor cost assumptions

Item	Purchase price Dollars	Fixed cost Dollars/SMH	Operating cost Dollars/PMH
Chain saw	635	0.44	3.65
Slasher	13,606	2.48	1.15
Loader[a]	58,686	7.52	11.04
Labor[b]	6.00	7.80	---

[a] Medium size, 15,000-20,000-pound-capacity loader mounted on trailer.
[b] Wages of \$6.00/SMH plus 30 percent payroll costs.

Slasher bucking and decking costs at the sampled production rate were \$4.49/100 ft³. If the loader and slasher operator also loads trucks, part of loader fixed costs and labor can be charged to loading. Assuming utilization of the loader and operator is 80 percent, slasher bucking and decking costs were reduced to \$3.30/100 ft³. It is important to note that this cost comparison is based on stem populations and skidder production rates that differed greatly between the two operations studied.

The low utilization level sampled at each study site indicated that actual production and costs for bucking, sorting, and decking were constrained by felling and skidding production rates. Only when felling and skidding production reaches the production levels shown in Figure 2 would bucking limit system output. Otherwise, felling and skidding would limit the system production rate. Consequently, it is more appropriate to compare costs at equal production rates, implicitly assuming that volume processed per SMH is regulated by felling and skidding. It also is appropriate to compare costs for identical turns of stems. In this case, unit fixed and labor costs are determined by the felling and skidding production rate. Operating costs are derived from production cycle-time estimates obtained from equations 3 and 4. In this comparison, the cost advantage of chain saw bucking versus slashing decreased from \$1.50/100 ft³ at 400 ft³/SMH to only \$0.80/100 ft³ at 1,200 ft³/SMH (Fig. 3).

The small differences created by turn volume and number of logs can be attributed to operating time per turn and operating cost per unit production. The difference between the two cost curves shown for each system can be attributed to turn volume, number of logs, and estimated cycle time. The resulting shifts in unit operating costs were approximately \$0.25/100 ft³ (Fig. 3).

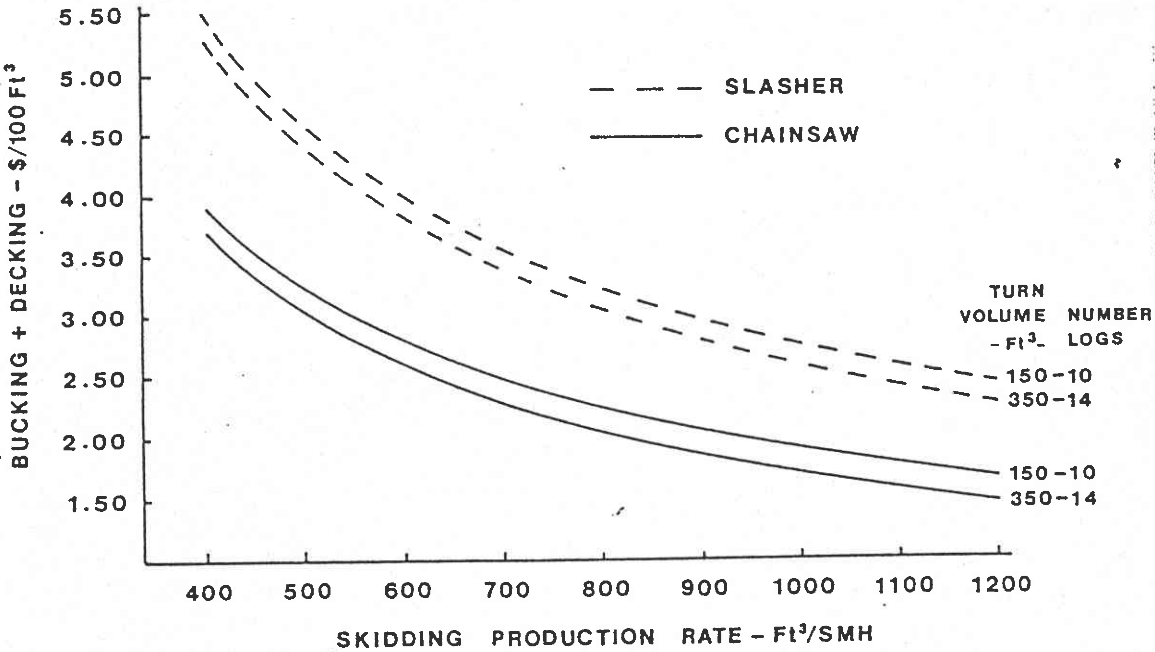

Figure 3--Estimated unit cost for two bucking, sorting, and decking methods when production rate is constrained by felling and skidding production.

DISCUSSION

Sampled and estimated production rates were much higher for chain saw bucking than for mechanized slashing and decking. However, the potential production rates of both methods often exceed the felling and skidding capacity attainable by many hardwood harvesting operations. When production is constrained by felling and skidding production, differences in unit costs between the two methods studied will be small. The cycle-time equations developed can be applied to determine potential bucking and decking production, and to identify situations where bucking may limit system output.

The low utilization levels sampled for bucking, sorting, and decking indicate that more time could be spent on product separation and sorting without adversely affecting the system production rate or harvesting cost. As a result, the marginal cost of added sorts would be low.

This is not to say that product mix would not affect harvesting cost. Harvesting smaller trees will increase felling and skidding cost. Market locations also will affect haul cost.

Other important criteria for comparing bucking and sorting systems include worker safety and log quality. The slasher operator seated at the loader controls is much safer than the chain saw operator working in a pile of decked stems near the working loader and skidders. Although log quality was not measured in this study, differences between bucking methods with respect to sawlog quality were readily apparent. Chain saw bucking frequently produced split logs or logs with excessive crook or sweep. The bucker had a poor view of stem quality when stems had been decked in a pile by the skidder. Stresses on decked stems also promote splitting during the bucking cut. Conversely, the slasher operator was in position to view the entire stem, and also turn or reposition the stem to improve log quality. In light of potential losses in product value in the bucking process, the cost difference between bucking methods might be negligible.

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