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Project ref: 500S/35/04

Chipper Review

Contents | Page

Contents Page

Tables

INTERNAL PROJECT INFORMATION NOTE 06/05

Project ref: 500S/35/04

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SUMMARY

A number of wood chippers available on the UK market are capable of producing biofuel Woodchips or Hog fuel as defined in the proposed European standard, CEN /TC335.

Ten chippers were chosen for trial, representing the range of available designs considered suitable for the production of wood fuel at the small scale.

Piece size and moisture content of the infeed material was recorded, and sampling of chip particle size was carried out in accordance with the procedure recommended in the proposed European Standard.

Relative performance in terms of output quantity and the quality of woodchips produced in relation to the proposed European standard was assessed.

In addition, operational practice, in terms of machine safety, manual handling and noise, was examined.

The overriding factor limiting output appears to be feed material handling time.

A significant limiting factor with regard to quality is the proportion of small diameter ‘end’ material per unit volume.

1. INTRODUCTION

The increasing importance of woodfuel in the UK, in terms of stated renewable energy policy and sustainable forest management, has highlighted the need for an indigenous woodfuel supply industry.

Woodchip is currently the main form of feedstock for automated wood-burning boilers, and there is increasing interest in the use of woodchips for heating domestic and industrial properties.

At present chip production systems, particularly small-scale systems are not well established in the UK. There is, therefore, a need to stimulate the development of such an industry. In order to help consolidate this development and demonstrate confidence in the potential of this market to small-scale producers, a range of chipping machinery was evaluated in relation to costs, outputs and performance, and product specification.

The majority of chippers in use in the UK are small-scale hand fed units. They are used for a variety of tasks and only a small percentage is used solely for the production of woodchips for burners. Depending on machine capabilities there is great potential for these existing machines to produce quality woodchips for the developing wood fuel market.

Some wood fuelled boiler feeding mechanisms demand a high degree of consistency of infeed material. Larger moving grate units are capable of accepting material with a wider range of moisture content, variation in particle size and a higher percentage of contaminants, whereas the woodchip specification for smaller sized boilers is especially critical.

Existing woodchip-heating schemes in the UK are small and few in numbers. The quantity requirements can easily be fulfilled using small-scale chippers.

The capabilities of small-scale chippers in terms of output are largely underestimated. Based on previous output data and with the correct infeed specification and sharp cutting edges, a small-scale chipper can produce approximately 5770 m^3 of round wood per year. A small Combined Heat and Power (CHP) plant would require between 2-3000 m^3 per year.

Quality woodchip production from small-scale chippers is a topic of great interest to the industry. There is little demand for large-scale production of woodchips in the UK, as this market is not yet established.

The aims of this report are to identify the capabilities of a range of small-scale equipment to produce Woodchip for biofuel as defined in the proposed CEN /TC335 standard, and to identify and investigate recent developments in chipper technology in relation to the production of woodfuel.

The key issues are:

- Machine suitability in relation to product as specified in the standard.
- Comparative costs and outputs of a range of machines.
- Comparative performance when loader-feeding or hand feeding, in terms of economic, ergonomic and end product variables.

The specific objectives of the report were to:

- Describe the characteristics of the generic types of chipper available
- Summarise recent technological developments and improvements in chipper design, and highlight performance in relation to specific site and job limitations
- Define costs and outputs within the parameters of the trial
- Define, as far as possible, optimum equipment settings for the production of woodfuel

Prior to finalising the trial rationale, a scoping study of the need to evaluate the use of a range of feedstock types was carried out (Annex 1). Forest harvesting residues, arboricultural arisings and sawmill co-products were considered in addition to standard roundwood products, and some practical tests carried out.

It was concluded that to examine such a range of material would require a more detailed classification of each type. It would also entail blade replacement and adjustment of settings and working method with each feedstock and machine combination. Such an investigation should be the subject of a separate study.

The relative economics of dry and green roundwood chipping was identified at the planning stage as an issue for examination. The project timescale and operational logistics would not permit a thorough investigation of this variable with comparable produce, however, and a decision was made to limit the range of feed material in this trial. However, previous study had shown that the most consistent chips were likely to be obtained using green rather than seasoned material[1].

2. TRIAL RATIONALE

It has been identified that the industry needs further information on small-scale woodchip production to stimulate the development of the market.

A wide range of woody material such as residues, arboricultural waste, slabwood and sawmill offcuts have the potential for woodchip production. However the variability in constituents, size and moisture content would require a thorough classification process to be undertaken before any comparable results could be produced from a trial.

[1] Technical Note 9/98 Woodfuel chipping: field trials.

Bearing in mind the more exacting specification for Woodchip as defined in the CEN standard, and the limitations of smaller boiler feed mechanisms, it was clear that a consistent feedstock would be likely to produce the best results in this instance. For any meaningful comparisons to be made between chip quality produced from the machines chosen for the trials a degree of consistency of infeed material was also required. It was also perceived that many opportunities for woodfuel chip production at the small scale would be likely to coincide with other woodland management operations, and that it would be beneficial to trial a commonly produced roundwood specification. The present market for small roundwood is generally perceived to be poor, and woodfuel could present a better economic opportunity for growers.

Infeed material had to be within the capabilities of the chipper in terms of diameter and be of a length, which could be handled safely by an operator. The use of a product commonly produced from harvesting operations would provide valuable information for small-scale production.

The design of chippers for use in the UK is strongly directed towards hand fed machines with operator safety protection on every one. Consultations with suppliers concluded that only a small number of loader fed machines were operating in the UK. It is therefore reasonable to assume that without further investment the greatest potential for woodchip production on a small-scale will be from the existing machines currently in use.

Considering these parameters the decision was made to use two-metre roundwood within the diameter range of the chippers trialed. This material could be handled safety by an operator using aid tools such as timber tongs.

3. MACHINE TYPES

There are three basic generic types of chipper mechanism available (disc, drum and screw, or cone screw) and it is important to consider the operational characteristics and capabilities of each.

3.1 Disc chippers

The most common type of chipper mechanism is based on a spinning disc, with blades set at right angles to the infeed rollers. Fitted to the back of this flywheel are paddles whose function is to eject the cut material through a spout. Blade alignment is generally radial, but the blades may be angled, curved or staggered in order to reduce stress, wear and power demand.

Material is cut against an anvil plate fixed to the machine casing, which allows adjustment of the clearance between disc and casing.

The disc paddles may have serrated edges, as may the machine casing. These serrations, combined with a narrow clearance, act as ‘sliver breakers’ so that oversized chips may thus be further broken down. There is likely to be an additional power requirement, however, and such devices may not be wholly effective with feedstock species with a long, tenacious, grain fibre.

Chip size overall can be influenced by several factors, the most important of which is the infeed roller speed. The faster the infeed, the larger the average chips, while a slower infeed may also produce a more consistent chip. The number of blades will also have an effect, with fewer blades producing larger chips. The speed of disc rotation may be varied, although there will be a minimum speed required to achieve sufficient air movement for chip outflow. Lastly, the angle of infeed may be varied from the perpendicular to reduce machine stress and produce shorter chips.

3.2 Drum chippers

In this type of mechanism, knives are mounted on a rotating drum, and material is either fed by rollers or infeed conveyor, or drawn in by the action of the drum and force of gravity. Blades are usually arranged along the length of the drum, but may be staggered rather than continuous. An anvil plate allows gap adjustment at the cutting edge, whilst the clearance between drum and casing normally increases behind this point to allow chip flow to the spout.

Airflow may be generated by a fan attached to the end of the drum, or by the blades themselves. Drum machines may be fitted with a screening system, rather than sliver breakers.

As with disc machines, chip size is influenced by infeed speed, blade frequency and adjustment, and drum rotation speed. Additionally, timber diameter will affect the angle at which the cut is made, and so influence chip size and consistency. Drum units are always fed at right angles to the drum.

Drum units are capable of chipping material across the full width of the drum, and can therefore incorporate a larger infeed 'throat' than equivalent sized disc machines, whose intake is limited by the radius of the disc (or discs). Optimum feedstock dimensions may also be determined by power and cutting speed, however.

Most drum machines can take a mixture of forest residues and small, twiggy material, and round wood lengths.

3.3 Screw chippers

In this type of chipper, not as common as the other two types in the UK, a conical screw spins in line with the infeed, and the cutting edges of the screw are used to draw in offered material. As with the other designs, material is cut against an anvil plate, which may be adjusted.

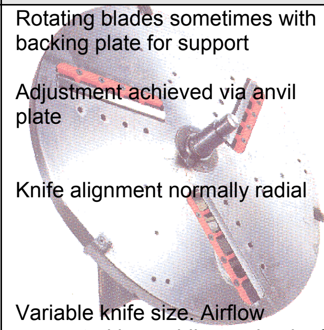
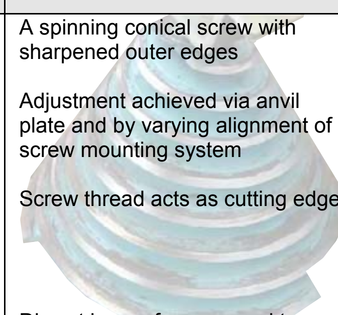
Blade alignment is fixed, as the cutting edge is integral to the screw. The screw pitch chiefly influences chip size, although slowing the machine may cause more oversize chips to be produced. There is no other means of adjusting the chip specification.

The cutting edge is continuous, and the timber is 'sliced' rather than 'chopped' into chips. In comparison with other designs, screw units are quieter and commonly use less power. The cutting edges are also less prone to damage from feed contaminants than disc or drum blades.

Airflow is achieved by the use of a disc attached to the base of the screw cone, and sliver breakers may be mounted at this point.

The characteristics of these three generic chipper types, and the operational implications of these, are summarised in Table 1.

Table 1. Individual characteristics of the three types of chipper

Considerations	**Type of chipper**		
	Disc	**Drum**	**Screw**
Design features	 Rotating blades sometimes with backing plate for support Adjustment achieved via anvil plate Knife alignment normally radial Variable knife size. Airflow generated by paddles on back of disc. Serrations on paddle can function as twig/sliver breakers	 Blades mounted around drum Adjustment achieved via anvil plate Knife alignment normally along drum, although there are exceptions, sometimes with backing plate for support Knives used to generate airflow; alternatively, a separate fan arrangement can be installed. Twig/sliver breakers are usually separate attachments	 A spinning conical screw with sharpened outer edges Adjustment achieved via anvil plate and by varying alignment of screw mounting system Screw thread acts as cutting edge Disc at base of screw used to generate airflow and may carry twig/sliver breakers
Factors influencing product (Chip size)	Infeed roller speed Number of knives Knife setting Disc speed Infeed angle	Infeed roller speed Number of knives Knife setting Drum speed Always fed at right angles to drum	Unlike disc and drum chippers the screw acts as the infeed mechanism; the screw size and pitch control the rate of infeed

Type characteristics	Smaller capacity units available as rated by engine/throat size etc. Knives are more sensitive to soil and wire contamination of the feedstock than the screw type.	Able to take infeed over the whole length of the drum cylinder. This feature means that drum chipper infeed tables are more readily adapted to conveyor mechanisms. Knives are more sensitive to soil and wire contamination of the feedstock than the Screw type. Flexible in their accommodation of differing feedstock.	Smaller capacity units available as rated by engine/throat size etc.

4. RECENT DEVELOPMENTS

4.1 Operator safety

The Health and Safety Executive (HSE) made new legislation for chipper design in 1992. To prevent operators being drawn towards the infeed rollers all new machines must be fitted with a safety trip. Depending on the height of the lower edge of the infeed chute this is mounted either along the bottom and sides or top and sides of the chute. In the latter instance, the lower edge of the chute must not be raised more than 600mm from the ground.

The distance from the edge of the infeed chute to the feed rollers should be no less than 1200mm. For machines that were built before 1992 a 'retro kit' can be fitted to ensure compliance with the HSE legislation.

On machines where the lower edge of the infeed chute is less than 600mm from the ground and the timber being offered to the machine is from stacks up to 1.8m in height, increased effort can be required by the operator to lower pieces of timber into the machine. Presentation for each type of machine is important to ensure efficiency in performance.

4.2 Operational efficiency

When an abnormal load, caused by an oversized or twisted section of timber, is placed on the machine, failure to stop the infeed can result in stalling of the engine. Most machines are now fitted with a 'no-stress' system. Electronic sensors stop the infeed rollers if a force of abnormal magnitude is applied to the cutting edge. Once the load is reduced or the offending section of timber has been removed the device can be easily reset by the operator.

Turntables enable the infeed chute to be positioned towards the material to be offered. This reduces the handling element of the job and can be a significant advantage where access is restricted. No machines with this feature were available for this trial, however.

Some chipper manufacturers have undertaken recent developments in the design of infeed roller grips. This development has resulted in an increased surface area of the grips coming into contact with the offered material and reduced slippage on wet and loose barked material. Slippage can cause variation in chip size and reduce performance. The Schliesing 550ZX used in the trial had curved toothed grips equally spaced on the rollers.

The design of the Greenmech machines is unusual in that it incorporates unique circular blades. This means that the cutting edges may be rotated to present a fresh sharp face, before needing to be removed for re-grinding or replacement. The blades are also arranged in a spiral pattern across the disc face, which serves to reduce impact.

4.3 Product quality

On the majority of chippers the cutting speed is directly related to the revolving speed of the flywheel. The Heizohack, a German machine specifically designed for producing woodchips for heating, has the drum-mounted cutting edges geared down from the flywheel resulting in a slower cutting speed. Multiple pieces of timber can be offered to the machine with a high level of consistency of chip size being achieved.

Longer particles can cause blockages in automated burner feed systems. These can occur once the small end section of a piece of timber passes the chipper infeed rollers. The wood then moves freely and is often cut longitudinally by the knives producing slivers or chunks.

There are two recent developments in design that prevent this occurring. On some disc chippers sliver breakers are attached to the back of the flywheel. These are metal lugs, which smash the slivers during rotation of the flywheel before the chips are ejected out of the discharge chute. None of the machines available for trial incorporate these as standard.

Interchangeable screens may be incorporated into the housing of drum chippers, depending on the size of chip required. Oversize chips are revolved around the drum until the size is reduced to fit through the screen.

5. MACHINE CHOICE FOR TRIALS

The choice of chippers available on the UK market is extensive. Most of these are designed and used solely for comminuting woody material into a more manageable form for dispersal on site or for ease of removal. Very few are used in the production of woodchips for heating, and consistency in particle size is rarely a primary consideration.

The wide range of wood chippers on the market required a selective approach to be taken. A combination of collective TD experience and consultation with manufacturers and suppliers formed the basis for machine selection. The ten machines chosen for trial were broadly representative of the range of models currently available, covering the three main chipper mechanism types in a range of size and power configurations. Consideration was given to machines which had either been designed with a view to woodfuel production, or which are currently in use for this purpose in the UK. Discussions with current and potential users also helped identify machines which are considered capable of producing woodfuel to a satisfactory standard.

5.1 Hand fed versus loader fed

The majority of chippers in use in the UK are designed as hand fed units. As such, they are fitted with safety features, which, while conforming to legislation, may vary from one model to another. Chippers solely dedicated to loader feeding do not require the same safety features as a hand fed machine.

Offering material to chippers by hand demands a high degree of lifting, bending and physical exertion. It is therefore critical that timber specified for chipping is within the handling capabilities of the operator. Presentation of material is a major consideration to ensure high productivity. The nature of hand feeding chippers requires the operator to be close to the cutting knives and the source of noise produced by chipping. In comparison most loaders have a greater lifting capacity and large grab area.

Chippers with integral loaders generally have a higher capital cost and require a skilled operator. The operator used in the trials was not familiar with the lever controls for the loader, but it is reasonable to assume that with an experienced operator and longer lengths of infeed material greater, outputs would be achieved when compared to an equivalent hand fed unit.

5.2 Three-point linkage mounted versus self-powered chippers

In instances where chippers are required to move frequently on public roads a self-powered trailer mounted chipper is often preferred to a PTO version. These machines are widely used in arboricultural operations as they can be moved at a higher road speed than a PTO version coupled to a conventional agricultural tractor.

The capital cost of a chipper with an independent engine is higher than the equivalent PTO version. Self-powered chippers are dedicated machines and a more continuous workload is required to make purchasing the machine economically viable. PTO versions have greater flexibility in that the motive power is not dedicated solely to the chipper and can be detached and used for other operations.

A higher degree of maintenance will be required for a self-powered chipper, due to the independent engine. Petrol versions have shorter service intervals than diesel engine versions.

5.3 Design

Basic chipper design of the machines tested was largely the same with each having an infeed chute, drum, disc or screw housing and a discharge chute.

Stress control was fitted to all the machines trialed except the TP VM 100, the TP 200 and the Laimet. A mechanical stress control device, a slip clutch on the PTO shaft, was fitted to the Jensen.

The Heizohack has been specifically designed by a wood burning boiler manufacturer who recognised the issues associated with the production of consistently sized woodchips for heating. This machine has a wide infeed conveyor allowing multiple piece feeding and cutting knives mounted on a drum. Unlike the majority of chippers the drum is geared down from the flywheel resulting in a slower cutting action and a lower power demand. The machine can be fitted with a variety of interchangeable screens allowing greater flexibility to produce a range of consistently sized woodchips.

5.4 Other considerations

Whilst attempting to represent the range of variation in chipper design available, consideration was also given to the comparison of machines with differing power requirements, and infeed material handling capabilities.

The production of woodchips that will conform to the proposed CEN standard may be achieved using a wide range of diameter classes for infeed material. However it was considered that the most readily available resource for producing woodchips at the small scale to the standards specified would be stemwood with a butt diameter range of 4cm to 25cm.

Seven disc machines were trialed, ranging from the diesel powered TP150 model, with 150mm maximum feed diameter, to the tractor mounted Schliesing, which takes material up to 260mm in diameter. The TP200 and Jensen machines are tractor mounted, while the Greenmech machines are self-powered.

The tractor mounted Farmi CH260 was selected for trial in both a loader-fed configuration, and as a hand loaded unit, to provide a comparison of the two methods.

Two drum chippers were tested. The gravity fed TP100 is a petrol driven machine suitable for small diameter material up to 100mm, whilst the Heizohack is a wheeled, PTO driven unit capable of taking feed material up to 400mm in diameter.

All chippers trialed, excluding the Heizohack and Laimet, used hydraulic rollers to draw the offered material to the cutting knives.

With the relatively standardised feed material used for this trial it was possible to standardise machine settings, in order to allow straightforward comparisons to be made. All blades and infeed adjustments were set to produce a medium sized chip, as defined by the manufacturer of each machine.

The quality of wood fuel produced in relation to the CEN TC/335 standard is shown in Table 5.

All machines were supplied in good working order with cutting edges either new, or sharpened to the manufacturer's specification. Specifications for each of these machines are detailed in Table 2.

Table 2. Suppliers' specifications and technical data

Model	Type	Cost	Feed Angle	Max. Diameter	PTO Speed/Shaft Type	Weight	Horse Power Demand
Heizohack HM5 -400	Drum	£25005	To 90^0	400mm	540 6 spline	3000kg	75 +
Laimet HP21	Screw cone	£9000	< 90^0	180mm	1000 & 540 6 spline	800kg	135 +
Schliesing 550 ZX	Disc	£17000	90^0	260mm	540 6 spline	1580kg	140
Farmi CH 260	Disc	£8000	45^0	260mm	540/1000 6 spline	1520 kg	40-90
Farmi CH 260 (Loader fed)	Disc	£19000	45^0	260mm	540/1000 6 spline	1550kg	40-90
TP 100 VM	Drum	£5000	~ 60^0	100mm	Self powered 16 hp	245kg	--------
TP 150	Disc	£11500	90^0	150mm	Self powered 27hp	490kg	--------
TP 200	Disc	£7000	90^0	200mm	1000	700kg	40-115
Jensen A240PTO	Disc	£14060	90^0	250mm	1000	1400kg	80 +
Greenmech M220MT 55	Disc - blades	£18450	90^0	220mm	Self powered 55hp	1380kg	---------
Greenmech 19-28 Arborist	Disc - blades	£16500	90^0	1875mm	Self powered 50hp	1220kg	---------

6. TRIAL METHOD

The trials were carried out on Cannock Chase, in West Midlands Forest District. Forest Enterprise supplied the timber from recent harvesting operations. The species used were Corsican Pine, *Pinus nigra var. maritima* and Birch*, Betula pendula*. All timber was stacked on bearers on a hard standing.

Throughout the trial all recommendations contained within the relevant safety guide, AFAG 604 *Use of Chippers*, were followed. In addition to the safety clothing recommended in AFAG 604 the operator used timber tongs to handle the short lengths. For ergonomic reasons each trial machine was positioned close to the timber stack to minimise operator movement without compromising safety.

Consideration was also given to published HSE guidelines for manual handling, with regard to lifting loads between head height and ground level, and reaching with loads.

All machines used in the trial were built after 1992 and as such conform to BS EN 294: 1992.

Each piece presented to the chipper was measured (mid diameter) and its volume calculated.

Sound pressure levels were recorded at the ear of the operator immediately after presenting timber to the chipper, these are shown in Table 3.

The operator for the majority of the trial was a member of Forestry Training Services, and was experienced in the use and maintenance of wood chippers.

Table 3. Machine performance

Chipper Model	Type and rpm.	Motive Power	Timber Input Species	Mean Volume (m^3)	Mean diameter (cm)	Output m^3/hour	Moisture Content %	Fuel Use (l/m^3)	Noise dB(A)
Heizohack HM5-400	Drum 540	Valtra T180	Birch	0.017	10	2.97	42.59	1.85	91 to 93
"	"	"	Pine	0.047	17	4.41	62.83	1.59	"
"	"	"	Pine	0.020	11	2.73	60.96	1.96	92
Laimet HP21	Screw 650	Valtra T180	Birch	0.014	9	2.85	45.18	1.97	94 to 95
"	800	"	Pine	0.016	10	2.65	60.65	2.62	94
Schliesing 550 ZX	Disc 1000	New Holland TM140	Birch	0.014	9	3.34	42.84	N/A	95
"	"	"	Pine	0.022	12	4.79	61.08	N/A	95
"	"	"	Pine	0.041	16	4.02	61.76	N/A	96
Farmi CH 260	Disc 1000	Valtra T180	Birch	0.014	9	2.74	40.54	3.71	95
"	"	"	Pine	0.019	11	3.85	62.90	2.51	95
"	"	"	Pine	0.043	16	6.89	46.01	1.85	96
TP 100VM	Drum	Self (16hp)	Birch	0.009	7	0.70	49.12	N/A	93
TP 150	Disc	Self (27hp)	Birch	0.012	8	1.67	51.01	N/A	94
"	"	"	Pine	0.018	11	1.96	62.74	N/A	94
TP 200	Disc 1000	Valtra T180	Birch	0.017	10	3.06	63.79	3.49	94
"	"	"	Pine	0.019	11	2.92	65.11	2.84	94
Farmi CH 260 c/w Loader	Disc (45° feed) 1000	Valtra 8150	Birch	0.044	16	4.95	46.33	3.53	N/A
"	"	"	Pine	0.011	8	2.46	63.36	"	N/A
"	"	"	Birch	0.010	8	2.41	43.75	"	N/A
Jensen A240	Disc 1000	Valtra 105 hp	Birch	0.017	10	4.17	37.10	N/A	118
"	"	"	Pine	0.020	11	5.08	59.98	1.28	117
Greenmech 19-28	Disc Blade	Self	Pine	0.018	10	5.29	59.11	N/A	N/A
"	"	"	Birch	0.017	10	4.20	38.04	N/A	N/A
Greenmech 220 Series	"	"	Birch	0.014	9	3.92	39.09	1.88	N/A
"	"	"	Pine	0.017	10	4.10	60.17	2.21	N/A

7. MEASUREMENT PROTOCOLS

7.1 Moisture Content Analysis

Samples of the woodchips were gathered from the heap produced and sealed in waterproof packages to prevent any moisture loss or gain.

A standard oven-dry method was used for sampling moisture content. Each sample was weighed before being placed in an oven at 105^0C + or – 3^0C for 24 hours. The chips were weighed at intervals and the dry weight of each sample obtained when no further weight loss occurred.

Moisture content was calculated by subtracting the weight of the dry sample from the wet weight, expressing the difference as a percentage of the original weight (Table 4):

Wet weight - dry weight/wet weight x 100 = moisture loss (%)

7.2 Particle Size Sampling

Sieves with aperture screens of 100 mm, 85 mm, 63 mm, 45 mm, 16 mm and 3.15 mm, as described in the draft CEN /TC335 standard, were tested. Dried chip samples were sieved through these, with horizontal agitation by hand, into large trays.

It quickly became apparent that most material passed through all but the two smallest screens with minimal agitation. If this method were to be used uncritically, a very significant underestimation of chip size, in terms of length, would inevitably occur in each category. This observation was borne out by results recorded during the preparation of the draft standard. The draft quotes errors in excess of 60% in this respect, using timed mechanised horizontal sieving with similar screens in series.

Without access to a mechanised grading system as described in the standard, and in light of these limitations to accuracy, it was decided to adapt the method to achieve an approximate grading by hand which was capable of comparison with the standard.

Samples were sieved using the 16 mm screen and those remaining in the sieve spread out evenly and visually assessed to ascertain average chip size. The largest chips were then sorted by hand and measured individually. These were separated into five size categories:

> 45 mm (where none were longer than 85 mm);
> 63 mm;
> 100 mm; and potentially
> 200 mm;
> 300 mm and
> 400 mm.

Where there were no chips longer than 100 mm, any longer than 85 mm were noted.

When no more obviously oversized (>45 mm) chips were found, the remaining sorted sample was assigned to an approximate size range, depending upon the smallest oversize category found, (for example >16 < 63 mm). The unsorted chips and fines, having passed through the 16 mm screen, were sieved again using the 3.15mm aperture screen to remove the smallest chips and fines. The chips remaining in the sieve were assigned to the size range > 3.15 to ~ 16 mm, the remainder being all that had passed through the 3.15 mm screen described as fines.

All these sub-samples were then weighed, and these weights compared with the weight of the original sample. This relationship is expressed as a percentage of the total dry weight of each sample in each size category (Table 4).

Table 4. Particle size of samples expressed as a percentage of the total sample dried weight

Chipper model	Species	>100mm	>85 to 100mm	>63 to 85mm	>45 to 63mm	>16 to 63mm	>16 to 45mm	>3.15 to ~16mm	Fines
Heizohack HM5-400	Birch						10.3	84.4	5.3
“ “	Pine						11.6	87.5	0.9
“ “	Pine				3.1		12.5	81.3	3.1
Laimet HP21	Birch	0.05		2.2		81.45		10.2	2.2
“ “	Pine			13.4	9.4		48.2	25.6	3.4
Scheising 550ZX	Birch	7.97			13.27		29.1	46.95	2.7
“ “	Pine			3.1	3.1		29.7	62.5	1.6
“ “	Pine	4.7	3.1	9.4	7.8		32.8	34.4	7.8
Farmi CH260	Birch			3.1	1.6		25.0	67.2	3.1
“ “	Pine			2.8		12.9		81.4	3.9
“ “	Pine				3.1		17.2	75.6	3.1
TP100VM	Birch			4.7	3.1		39.1	50.0	3.1
TP150	Birch				3.1		21.9	71.9	3.1
“ “	Pine				3.1		14.1	78.1	4.7
TP200	Birch				3.1		20.3	75.0	1.6
“ “	Pine			1.6	3.1		25.0	67.2	3.1
Jensen A240	Birch	4.1	0.6	3.2	6.0		51.1	33.2	1.7
“ “	Pine	1.3	1.5	3.3	7.8		38.2	45.1	2.9
Farmi CH260 c/w loader	Birch		0.01	1.95	7.86		70.48	18.54	1.17
“ “	Birch			2.6	6.3		50.3	38.5	2.3
“ “	Pine	0.2		2.3	4.0		57.5	32.9	3.2
Greenmech 19-28 Arborist	Pine	0.3	0.3	0.3	1.3		8.4	81.8	7.6
“ “	Birch	0.6	0.2	1.3	1.8		36.1	54.6	5.4
Greenmech 220 MT55	Birch	2.3	1.0	1.5	3.2		24.3	63.4	4.4
“ “	Pine	0.4		2.1	1.4		21.5	67.5	7.1

8. RESULTS

Species appears to have no effect upon output quantity or quality overall, but a larger mean piece size corresponds in most cases to a slightly increased volume output. The trend is not consistent, however, and the differences are not thought to be significant, beyond confirming the observation that increased handling limits production.

The average Moisture Content over all samples collected was approximately 55% (wet basis), but Birch was generally drier than Pine, with a greater variation. There is a slight trend apparent, in that output generally decreases with increased moisture content, but the differences are not significant.

Individual machine performance, as set out in Table 3, is described here with additional reference to operational, ergonomic and health and safety issues, as observed during the trial.

Chip sample quality in terms of particle size distribution, as set out in Table 4, is also described.

8.1 Heizohack HM5-400

8.1.1 Operator safety

The safety stop/reverse control along the bottom and sides of the hopper is connected by wire cable rather than solid bars and performed well during the trial. The only drawback during the trial was when material missed the edge of the hopper and rested on the cable, operating the stop. Material offered to the machine with branches or snags or pegs attached may also trigger the wire cable.

Once started the "max" button on the no-stress system must be held until a red light on the unit remains lit. At this point the infeed system takes up drive. This means that the risk of accidental infeed is reduced, as the machine does not automatically commence feeding while the operator is still in the tractor cab.

This was the quietest of all the machines trialed, with overall noise levels lower than those produced by the small TP100.

8.1.2 Operational efficiency

Connection to the tractor is by drawbar. The stand used when parking the machine is hand-wound, and geared to require little physical effort, but operation is slow. The other connections are the PTO shaft and a 9-pin electrical socket for the no-stress system.

The infeed hopper is wide and at a comfortable height, and a powered conveyor allows a full load of three to five lengths of material to be on the infeed at any one time. Coupled with a steady infeed speed this makes the machine easy to operate up to its capacity. The no-stress system was not triggered during the trial and the machine coped easily with the material. It also had the lowest fuel consumption overall, among the tractor mounted units.

Putting the machine into its transport mode involves turning the spout to a safe position and lifting the infeed hopper bottom plate and securing it with a pin. The plate requires some effort to lift even though assisted by a gas strut. The machine tows in line with the tractor.

8.1.3 Output

Output ranged from approximately $3m^3$ to over $4m^3$ per hour, depending on piece size, and the chips produced were of a high quality, falling within a narrow size range, and with no slivers or chunks found.

8.1.4 Product quality

Particle size fractions are closely comparable with the CEN P45 classification (Table 5), and as such would be suitable for 'household use' as described there. When chipping drier Birch, there was an increase in fines produced, and if a very high quality woodchip, suitable for use in the most demanding small domestic burner types, were required, this might be a limitation.

Table 5. Particle size for woodchips and hog fuel (CEN TC335)

Type of wood fuel	Main fraction (> 80 w-%)	Fine fraction (<5 w-%)	Coarse fraction, max. particle length
P16: Woodchips	$3.15 \leq P \leq 16$ mm	< 1 mm	< 1 w-% > 45 mm, all < 85 mm
P45: Woodchips and hog fuel	$3.15 \leq P \leq 45$ mm	< 1 mm	< 1 w-% > 63 mm
P65 Woodchips and hog fuel	$3.15 \leq P \leq 63$ mm	< 1 mm	< 1 w-% > 100 mm
P100: Hog fuel	$3.15 \leq P \leq 100$ mm	< 1 mm	< 1 w-% > 200 mm
P300: Hog fuel	$3.15 \leq P \leq 300$ mm	< 1 mm	< 1 w-% > 400 mm

8.2 Laimet HP21

8.2.1 Operator safety

The safety stop on this unit is in the form of solid bar, which runs along the top and around the sides of the infeed hopper.

The infeed mechanism is also the chipping mechanism, which means that the machine is live as soon as the PTO is engaged in the tractor cab.

Infeed is fast and aggressive, leaving little time to release aid tools such as lifting tongs. This leads to a tendency to avoid using timber-handling aids when feeding the Laimet.

8.2.2 Operational efficiency

The pins for connecting to the three-point linkage are very low. This meant that the link arms on the tractor could not be lowered beneath the pins to make use of the auto hitch. This would not be the case were the machine left on blocks when not in use.

The only other connection is the PTO shaft. This machine is not fitted with any form of no-stress system. Other than engaging the PTO drive there is no other operator input required.

The infeed hopper is small and very low when the machine is lowered to the ground. The bottom of the hopper cannot be raised higher than 600mm as the infeed protection bar runs along the sides and across the top of the hopper.

The inner end of the infeed hopper is rectangular in profile and the operator must orientate any material with bends to pass through this. On one occasion when fed incorrectly, a piece lodged in the infeed system, requiring considerable effort to dislodge it.

The absence a no-stress system poses a major problem as, once engaged in the chip mechanism, the timber either passes right through, or stalls the tractor. The 180hp Valtra used in the trial gave little indication of impending stall and was brought to a stop on three occasions.

On the third occasion the emergency stop bar failed to operate. Once the cover was removed it appeared the safety gate in front of the screw had lifted too high and was sitting above the actuating pin.
When feeding timber close to the machine’s maximum the only options appear to be that pieces are cut much shorter than 2m, or that the operator remain close to the safety bar and be prepared to operate it.

Transport is simply a matter of turning the spout so it does not create a hazard to other road users and raising the machine on the three-point linkage. It runs within the width of the tractor but is quite long and tail swing is an issue when turning.

8.2.3 Output

Output was close to 3m^3 per hour, with 9cm diameter material, falling to 2.65m^3 with 10cm Pine, and the chips produced were of good quality with few fines.

8.2.4 Product quality

Although a number of larger chips were produced, only one sliver over 100mm was found in the sample. The particle size distribution of the sample as shown in Table 4 is fairly broad, but corresponds closely to the CEN P65 standard. As such, the product would be suitable for most burner specifications, including those intended for ‘household use’ as it is described in the standard.

8.3 Schliesing 550ZX

8.3.1 Operator safety

The safety stop is a solid bar, which runs along the bottom and around the sides of the infeed hopper, allowing the unit to be raised above 600mm from the ground on the three-point linkage.

8.3.2 Operational efficiency

The mounting pins on the Schliesing are high enough to allow the use of the quick hitch system fitted to modern tractors. The other connections are PTO and 9-pin electrical socket to power the no-stress system.

Powerful feed rollers and adjustable no-stress control makes this machine easy to work. None of the material on the test gave it particular problems.

When transported, the unit runs within the width of the tractor although, as with the Laimet, there is a potential problem with tail swing when turning.

8.3.3 Output

Output was over 3 m^3 with 9 cm material, rising to almost 5 m^3 per hour, although the chips produced had a number of slivers over 100 mm as well as a higher proportion of fines with one of the Pine samples.

8.3.4 Product quality

At best, the samples could be compared with the CEN P65 standard, but overall the product would be described as P100 hog fuel, rather than high quality Woodchip. This might still be acceptable for most burner types, but would not meet the more demanding specification for household use.

8.4 Farmi CH260

8.4.1 Operator safety

A safety stop bar runs along the top and down the sides of the hopper, which means that when hand-fed, the unit cannot be raised more than 600mm from the ground. An emergency stop is not fitted to the loader fed unit.

8.4.2 Operational efficiency

The infeed on the Farmi is at 45 degrees to the disc, which serves to reduce machine stress and probably influences the high chip quality.

All machines studied were hand fed, whilst the Farmi was also loader fed. No output difference was observable between the two feeding methods.

Typically, the loader feeding cycle can be just as interrupted as the hand feeding cycle, and the input platform on the Farmi could not accommodate the full grab of timber the loader was capable of handling. The loader therefore had to wait, or try to assist infeeding. This limitation was compounded by small piece size, and the short lengths used.

8.4.3 Output

Output throughout was comparatively high, reaching almost 7m^3 per hour when hand feeding 16cm material. Surprisingly, this dropped to around 5m^3 per hour when a loader was used.

8.4.4 Product quality

The chips produced were of a high quality, with few larger chips and almost none over 100mm, and few fines. Overall, the particle size distribution corresponds to CEN P65, and as such would be suitable for household use as described in the standard.

8.5 Jensen A240 PTO

8.5.1 Operator safety

The emergency stop bars are fitted around the sides and below the edge of the infeed chute, so the unit may be lifted to a comfortable working height. Horizontally mounted infeed rollers are geared together and the upper roller spring mounted to ‘enclose’ infeed material. This maintains the infeed and restricts the gap through which any debris could be ejected toward the operator.

8.5.2 Operational efficiency

The infeed chute slopes slightly, away from the rollers, to prevent contaminants being drawn into contact with the blades.

The PTO connection is fitted with a clutch, so that the shaft is disengaged if any abnormal load is exerted on the flywheel. There is no electrical resetting device, this having been replaced by a mechanical system.

The machine has been designed so that the draft effect from the flywheel also cools the hydraulic oil, while the spout and casing surrounding the flywheel have been treated with noise damping paint. This was the noisiest machine recorded during the short trial period, however.

8.5.3 Output

Output was 4–5 m^3 per hour with 10–11 cm material. The chips sampled covered a relatively wide range of particle size, with some quite large slivers produced, though very few fines.

8.5.4 Product quality

Samples closely correspond with CEN P100, which would be described as Hog fuel. This might be acceptable for most burner types, though not for the most exacting specifications, defined here as those intended for household use.

8.6 TP 100VM

8.6.1 Operator safety

The machine is fitted with a spring-loaded steel sheet, which closes off the hopper once the material being chipped drops below a certain length c.0.5m; this was damaged on the trial machine and would not stay in place. Without it, the machine can eject pieces up to a foot long out of the hopper, forcing the operator to stand clear and wait before picking up the next piece.

A right-handed operator will tend to stand to the left side of the machine, which is where most manufacturers mount the controls. The negative affect of this is to put the operator alongside the exhaust outlet for the petrol engine.

8.6.2 Operational efficiency

The TP100 was easy to use, and worked well. It has an unusual type of stress control in that it is designed to allow material, as it gets shorter and lighter to bounce on the chip blades, allowing the machine to gain revs.

8.6.3 Output

Output was low at less than one cubic metre an hour, and only Birch was used, due to the limited diameter specification for the machine. A low output might be expected with such a small unit and a small piece size, but the above-mentioned handling delays might also play a part.

The chips produced were of good quality, with few large pieces and few fines.

8.7 TP150

8.7.1 Operator safety

Safety stop/reverse bars are fitted around the top and sides of the infeed chute.

8.7.2 Operational efficiency

The TP150 trialed was self-powered with a diesel engine, and stress control. This machine coped easily with all the offered material, the no-stress system taking over whenever required.

8.7.3 Output

Output at almost 2 m^3 per hour was more than twice that of the smaller machine, albeit with a larger piece size. The chips produced were of similar quality.

8.8 TP200

8.8.1 Operator safety

A safety stop/reverse bar runs along the bottom and around the sides of the infeed chute.

8.8.2 Operational efficiency

The TP200 is tractor mounted with pins high enough to allow the use of the quick hitch. This machine is not fitted with a no-stress system.

Easy to feed and with a good hopper height this machine coped well with all the material, though the feed rollers struggled to grip material at the top end of the size range. Larger pieces had to be pushed forcefully into the feed rollers making it more difficult to chip heavy material.

8.8.3 Output

Output was around 3 m^3 per hour with 10–11 cm material, with good quality chip again produced.

8.8.4 Product quality

All the samples from the TP machines trialed are closely comparable to CEN P65, and as such would be considered suitable for household use. Only the number of fines produced might prevent full compliance with this classification.

8.9 Greenmech 19-28 Arborist and 220 series

8.9.1 Operator safety

The infeed hopper on the Arborist is less than 600mm from the ground, and is fitted with a top and side safety bar. On the 220 machine, the safety bar runs along the bottom and around the sides of the infeed.

8.9.2 Operational efficiency

The circular blades on these machines are arranged in a spiral pattern across the disc face, which serves to reduce impact. This partly compensates for an infeeding angle at 90 degrees to the disc.

No Greenmech machines are currently made with an angled infeed, and neither machine tested had sliver breakers, though they are available to special order.

Overall this machinery appears soundly made, and performed well.

8.9.3 Output

Output of these machines was consistently high with 10-11cm material, at around 4m3 to over 5m3 per hour. The chips produced covered a relatively wide range of particle size, with a higher proportion of fines overall than the other machines tested.

8.9.4 Product quality

Although all but one of the samples contain sufficiently few large slivers to meet the P65 classification, the number of fines produced might mean that the product would be unacceptable for household use as described here.

The results of the chip sample grading (Table 4) can be compared with the definitions of Main, Coarse and Fine fractions for the five classes of woodchips and hog fuel as set out in the CEN /TC335 standard (Table 5 reproduced from the draft standard).

In most cases, there is a clear indication of the class into which the trial sample is likely to fall. Difficulty arises only when the fraction is close to the cut-off point for a particular class. In such instances a higher degree of accuracy in grading would be required. In all cases, the fine fraction recorded during sampling covers a larger particle size range than that defined in the standard, as a 1mm screen was not used. Even so, most machines produced few fines, and a number of the chip samples clearly meet the requirements for high quality woodchip recommended for household usage. This is defined in the CEN standard as chips from material of stem wood origin, with dimensions corresponding to P16, P45 or P65, as shown in Table 5.

It is important to note that these results have been obtained from relatively small samples of material, gathered within a limited period of operation with each machine.

9. MACHINE COSTS

The purchase price for all the chippers was obtained from the respective agents or suppliers. None of the machines trialed were used exclusively for the production of woodchips for heating. Discussions with manufacturers and a wood fuel producer group provided guidance on the hourly usage per year and life expectancy of the machines. These figures (given in Table 6) have been used when calculating the values for each machine, but it should be noted that they are at best 'guesstimates' for the purposes of providing indicative hourly costs for the production of woodchips for heating only.

The hourly rate for the operator is based on the current Forestry Commission rate for a skilled forest craftsman. One operator was used for the trials.

Table 6. Comparative machine costs.

Cost Element	Heizohack HM5 -400	Laimet HP21	Schliesing 550ZX	Farmi CH260	TP100 VM	TP150
Capital cost (£)	25005	9000	17000	8000	5000	11500
Residual value	2505	900	1700	800	500	1150
Life in hours	3000	3000	3000	3000	3000	3000
Hours/year	300	300	300	300	300	300
Interest rate	0.05	0.05	0.05	0.05	0.05	0.05
Discount factor	0.6139	0.6139	0.6139	0.6139	0.6139	0.6139
Equivalent annual cost	0.1295	0.1295	0.1295	0.1295	0.1295	0.1295
Capital cost/ hour	10.13	3.65	6.89	3.24	2.03	4.66
Operating costs						
Repair/maintenance	2.00	2.00	2.00	2.00	2.20	2.20
Fuel	2.06	2.15	2.15[2]	3.98	1.40[2]	1.40[2]
Operator costs (£)	7.05	7.05	7.05	7.05	7.05	7.05
Tractor hire (£)	9.38	9.38	9.38	9.38	---------------	---------------
Total cost (hr)	**30.62**	**24.23**	**27.47**	**25.65**	**10.48**	**15.31**
Total cost (m^3)[3]	10.31	9.14	5.00	8.02	14.97[4]	7.80 9.17

[2] No actual figure available. Estimated by comparison with similar machines.

[3] Costs per m^3 are based on figures for chipping a standardised 10cm mid diameter piece size and species difference is colour coded for fair comparison. (Key: Pine / Birch).

[4] Due to its small size and power this machine was limited in capacity. It did not chip any piece larger than 9cm mid-diameter on this trial. Cost per m^3 figure is given for material of 9 cm mean diameter.

Table 6. Comparative machine costs (continued).

Cost Element	TP200	Farmi CH260 c/w loader	Jensen A240	Greenmech 19 -28	Greenmech 220 series
Capital cost (£)	7000	19000	14060	18450	16500
Residual value	700	1900	1406	1845	1650
Life in hours	3000	3000	3000	3000	3000
Hours/year	300	300	300	300	300
Interest rate	0.05	0.05	0.05	0.05	0.05
Discount factor	0.6139	0.6139	0.6139	0.6139	0.6139
Equivalent annual cost	0.1295	0.1295	0.1295	0.1295	0.1295
Capital cost/ hour	2.84	7.70	5.70	7.48	6.69
Operating costs (£)					
Repair/maintenance	2.00	2.50	2.00	2.20	2.20
Fuel	4.84	4.78[2]	2.21	2.79[2]	2.79[2]
Operator (£)	7.05	7.05	7.05	7.05	7.05
Tractor hire (£)	9.38	9.38	9.38	-----------------	-----------------
Total cost (hr)	**26.11**	**31.41**	**26.34**	**19.52**	**18.73**
Total cost (m^3)	8.53	8.27	6.32	3.69 4.65	4.57

10. DISCUSSION

10.1 Manual Handling and Operator Safety

Hand feeding chippers demands physical exertion, and because of the frequency of bending the lower back can be prone to injury.

Aggressive infeed rollers can cause the timber length to kick violently upwards or sideways at the outer end. This occurred several times during the trials, when hand feeding the Farmi. This sudden movement can catch the operator unawares, and care must be taken when loading. Risk to the operator is increased when longer lengths are presented. With all chippers, there is also a risk of material being ejected from the machine back towards the operator.

Wind direction affects the position from which the operator can offer material to the chipper. Even a slight breeze separates the finer dust particles from the chipper outflow, and stronger gusts can scatter the woodchips away from the intended delivery position. Respiratory protection may be necessary in dry, windy conditions.

10.2 Noise

Table 3 illustrates operator sound pressure exposure. Due to the 'megaphone effect' of the conical shaped, sheet metal infeed chute, noise is noticeably concentrated into the very position the operator stands to load the machine. Where noise levels exceed 85 dBA a higher level of ear protection is required, regardless of length of exposure. Some high output machines were especially noisy, and would require special operator protection as regards ear defenders, as well as possibly limiting daily exposure.

Some, noticeably improved, designs of machinery have achieved reduced operational noise levels as a by-product of other operational improvements. For example, reducing the speed of the cutters to gain a more consistent chip quality and a higher diameter capability, and separating them from the flywheel, to retain the chip blowing capability. This reduces the noise, which comes mainly from blade impacts, and is a factor of the cutting speed.

In this trial, only sound pressure level exposure to the operator was assessed. Sound power levels affect the noise transmitted to both the operator and the environment in which the chipper is working. Assessment of these in future trials would provide a fuller indication of noise pollution implications.

10.3 Production limitations

Physical exertion is a crucial limiting factor in production. The operator is often unable to keep up with the speed of chipping. A possible approach could be to use two operators, and although this would increase output, operating costs would be proportionally higher, and two or more operators could lead to accidents in the restricted area around the chipper infeed chute. Machinery design is another consideration; the Heizohack for example has a wider throat and infeed chute, whereby the infeed mechanism is able to take several pieces at the same time. So the machine does not have the same infeed restriction if used by two operators, or if one operator feeds a number of small pieces simultaneously.

Ultimately, the answer is to remove physical exertion and operator exposure completely with a mechanised loading system. Simply incorporating a hydraulic loader is not an adequate solution, however, as the Farmi studies show. For three-point linkage mounted loader fed chippers there is limited visibility from the operating position. Multiple piece loading can be difficult where the infeed aperture is narrow. Two metre lengths were inappropriate for loader feeding the Farmi as the restricted visibility prevented the operator from positioning the pieces onto the infeed rollers. A suitable chipper infeed 'deck' must complement the loader, which is capable of accepting full loader grabs.

An example of the hand feeding limitation was seen during the trial of the Jensen chipper. A high output machine such as this is more influenced by the effect. Time studies showed that only 50 to 54% of machine running time was taken up with actual chipping. The remainder was machine idling time whilst the operator was loading new material.

There are several other common aspects that limit optimal production. Chief among these is timber diameter. Some surprising indications of this were seen during the trials, when some machines stalled by timber diameters that were within their capabilities as indicated in the manufacturer's literature. This may not be an indication that the literature is incorrect, but only an illustration of the effects of different timber species and moisture content. Wet timber, especially the pine, tended to show an increased effect.

Bent and twisted material can jam in the chipper throat. This varied with individual machines. The narrower the chipper throats the more sensitive the machine, although drum chippers seemed to be the least sensitive of all the designs.

Another important aspect is timber length. Longer pieces will allow a longer machine chipping cycle, but will add to the stresses of hand loading, hence the compromise on two metre lengths in these trials. These short pieces can lead to a reduction in quality, however. The majority of poor quality chip results from oversize 'slivers', which characteristically occurs when the last chunk at the end of a piece turns sideways after passing the infeed rollers and before being chipped by the blades. The incidence is therefore proportional to the number of pieces fed in, and the cross-sectional size of 'ends' cut, per unit of volume. This characteristic may consequently be reduced by infeeding a longer average piece size, and/or pieces with smaller tip diameters. Whole delimbed stem-wood with a very small tip diameter (~ 3 cm) fed into the chipper butt first can optimally reduce the effect, as well as maximising output. Clearly, such a specification could only be machine loaded.

10.4 Costs and outputs

Table 3 gives an indication of the very wide variation in outputs between machines and Table 6 gives an indication of the cost per hour and per unit volume. Of itself, a high output may not be beneficial if seasonal production demand is much less than the annual capability. Such a situation will inevitably lead to under-utilisation of machinery and consequently higher, uncompetitive costs. The correct choice of machine is one that will best provide a balance between cost and output requirements.

Machine power would appear to have no effect on chip quality. Comparable results were achieved across a range of inputs, from the 12 hp of the TP100 to the 100+ hp of the Laimet or Farmi. The Schliesing, Jensen and Greenmech machines although capable of high outputs, did not produce a high quality chip suitable for household use as described in the CEN standard. However the similarly sized Heizohack, despite having a lower output, due to a slower cutting speed, produced the highest quality of chip among the machines trialed.

All the machines trialed may be capable of producing an acceptable grade of woodfuel chip, dependent upon individual boiler feed specifications. The cost per unit volume varies according to quality as well as output, with the ‘cheapest’ chips produced being classified as ‘hog fuel’ according to the standard. Individual requirements as regards boiler feed specifications will be the deciding factor in machine choice. Further work with individual machines would be necessary to indicate the best balance between costs, outputs and quality for any given burner specification.

This trial specifically aimed to evaluated a range of chippers that may be suitable for small woodland owners producing woodchips, or for local woodchip producer groups. On a larger scale there is potential to produce large volumes of woodchips from commercial harvesting operations.

10.5 Factors influencing optimum equipment settings

The optimum equipment setting is the one that will produce a quality of woodchips that will conform to category P16 of the CEN standard, or the standard recommended by the burner manufacturer. The variables that will influence the optimum setting are infeed roller/conveyor speeds, cutting edges of knives, blades or screws, and the type and specification of presented material.

10.6 Contaminants

It was observed on all machines that the lower part of the infeed chute was a complete sheet of metal. Debris such as small pieces of bark, stones and other contaminants that are shaken from the offered material by machine vibration, accumulated in the infeed chute. Although some infeed chutes were angled downwards away from the rollers this unwanted material was drawn towards the blades by subsequent offered pieces. Contaminants coming into contact with the cutting edges reduce machine performance and increase the frequency of blade sharpening. It was considered that slots cut into the metal sheet would allow some of the contaminants to drop out of the infeed chute, thereby protecting the blades.

11. CONCLUSIONS

- There are very few chippers specifically designed solely for the production of woodchips for heating.

- It is very noticeable that a machine such as the Heizohack, which has been especially designed for woodfuel chip production, gives a very high quality product.

- There is no clear relationship between species and machine output or chip quality.

- There is no clear relationship between chip quality and mean piece size, as long as material is within the machine’s capacity.

- The physical effort involved infeeding material into a machine is a significant factor affecting both operator and machine performance.

- The recommended lifting capacity for a person of a given weight and height restricts the type of material that can be hand fed.

- The orientation, height and presentation of material to be offered to the chipper are all critical, and will directly affect performance and outputs.

- There are many safety considerations when using chippers. All operators should wear protective clothing as recommended by AFAG guide 604. Adequate training is a prerequisite for safe and efficient operation.

12. RECOMMENDATIONS

- Infeed material should be as long as is manageable, to maximise both quality and output.
- In many small-scale situations hand fed machines are likely to be used for the production of woodchips. Further research work should be undertaken to identify the optimum length(s) of material in relation to extraction, stacking and presentation to the chipper.
- Sound power level assessments should be made in future chipper trials.
- Future research work should aim to investigate the methods of large-scale woodchip production as part of an integrated harvesting operation.
- Woodchip production is a single element in the wood fuel chain. To further support the emerging wood fuel market, information should be sought and made available to link the other elements of the supply chain for woodchip production, including optimum raw material length and presentation, storage and transport to the point of burning.
- Further evaluation using the range of feedstock materials available is recommended.

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Annex 1

Scoping study of the need to evaluate the range of feedstocks available (other than stemwood), and the factors, which influence their chipping to acceptable standards

1. Introduction

There are significant quantities of material available to the bioenergy markets that are from sources other than forest and plantation woods. This material will require subsequent processing (**chipping**) before it enters the woodfuel market, and is likely to be the subject of future production studies.

However, before any further production studies are undertaken, it is necessary to identify the factors, which need to be considered in order to identify future chipping study requirements.

At the time of writing this report current knowledge, user and industry guidance, requests for additional guidance and potential market developments indicate that the following information is needed to support future industry growth and understanding.

2. Information needs

2.1.Under the heading of **general considerations** the following will need to be clearly identified:

Forms available:

- SRC/SRF (The effects of form on storage/storage on form, storage drying and optimum piece size in terms of length and diameter)
- Harvesting residues (Fresh/Green, including leaves and needles, Dry, Blends and mixtures, stumps)
- Arboricultural arisings (Fresh/Green, including leaves and needles, Dry, Blends and mixtures)
- Sawmill residues (wood, wood/bark,)
- Wood other (Salvage wood, clean/mixed, treated/untreated, other contaminants)

Quantities available (Regional basis throughout the UK)
Potential end uses and future energy need projects (Suitability of material for a range of end uses)
Quality issues relating to the various forms (Identification of any salient issues, and how these might be influenced during production, sorting, storage and transport)

2.2. Under the heading of **issues specific to handling:**

Material sorting (the value/need to sort, methods, costs, outputs)
Material handling (Methods in relation to storage/transport/infeed, costs, outputs)
Material storage (Method, cost, H&S implications, environmental implications, security)
Transportation (Methods, costs, outputs)

2.3. Under the heading of **issues specific to chipping:**

Equipment options (relating to specification/design/peripheral equipment, required outputs, standards, machine cost, maintenance)
Method development (In relation to form, current practice/best practice development in relation to material form)
Performance (In relation to form, ergonomics, H&S considerations, environmental, costs, outputs)
Quality (in relation to known standards, identify which standards apply for range of feed stocks. Where none available consider development of)
Standards (existing/refinement/development of)

3. Other considerations

It is recommended that **large-scale forest residue harvesting** using terrain chippers and bailing equipment should be considered as a stand-alone project. The complexity of the issues involved, many of which fall outside the scope of any current chipping project, and the number of ongoing and proposed projects throughout the UK, under the specific heading of residue harvesting, support this recommendation.