Abstract
Waste materials of plant origin, e.g. sawdust, shavings, wood dust, corn, rape straw, or buckwheat hulls, can be used as a valuable ecological fuel. Combustion of different forms of materials of plant origin, i.e. biomass, is beneficial from the ecological point of view and is a rich source of energy. The paper presents selected devices for the production of heating pellets and briquettes (ecological solid fuel) from biomass. The devices with a flat immovable matrix working system are a beneficial solution in the production of solid fuels in small- and medium-sized plants.

1. Introduction
A rich source of energy from biomass is also the agriculture and food industry, which generates huge amounts of post-production waste (e.g. buckwheat hulls obtained during the production process of groats in grain processing plants, fruit pomace left over from the production of fruit juices, or herbal waste).

Waste materials of plant origin: sawdust, shavings, wood dust, corn, rape straw, buckwheat hulls, etc. can be used as a valuable ecological fuel. Combustion of different forms materials of plant origin, i.e. biomass, is beneficial from the ecological point of view and is a rich source of energy. For instance, the calorific value of straw is 15-17 MJ/kg at moisture level of approx. 10%.

One of the methods of converting biomass (including waste biomass) into energy is producing solid fuels in the form of pellets or briquettes through pressure agglomeration.

Owing to their numerous advantages these materials find widespread use, especially in the production of fodder and ecological solid fuel from waste materials of plant origin. A disadvantage of technologies for the production of both pellets and briquettes is their high power demand and fast wear of the working elements of the pelletising and briquetting devices [3,5].

2. The production of pellets and briquettes
The flow chart of the production of pellets and briquettes from biomass is presented in fig. 1.

![Flow chart of the production of pellets and briquettes](image-url)

**Fig. 1.** The flow chart of the production of pellets and briquettes (it was assumed that the moisture content of biomass is lower than 20% and it does not require drying)
Pelletisation or briquetisation of materials of plant origin is a process in the course of which shredded material, as the result of external and internal forces, undergoes densification, and the obtained product acquires a specific, permanent geometrical form [4,5,8].

Depending on the size of a product from biomass, it is called pellets (e.g. a diameter of 2 to 12-15 mm) or briquette (over 15-20 mm) [1,2,5,6,9].

Examples of the pellets and briquettes obtained in a working system with a flat immovable matrix are shown in fig. 2.

![Fig. 2. Examples of pellets (4,5,6 – a diameter of 4:6.5; 8.5 mm) and briquettes (1,2,3 – a diameter of 28 mm; 50 mm) from biomass](image)

### 2. Devices for the production of pellets

Schemes of working systems most commonly used in densification devices are presented in fig. 3.

![Fig. 3. Scheme of briquetting working systems: a) with a closed densification chamber: 1-eccentricity, 2-piston, 3-screw feeder, 4-densification chamber, 5-chamber sealing, b) with an open densification chamber: 1-piston, 2-crankshaft, 3-densification chamber, 4-briquettes, 5-heating elements, 6-screw feeder, 7-sawdust, c) with a screw working system, 1-densification screw, 2-matrix, 3-cone pin, d) the “flat matrix-densification rolls” working system: 1-densification roll, 2-material, 3-matrix, 4-agglomerate e) the “ring matrix-densification rolls” working system [6](image)

Fig. 4 shows the construction of an example pellet mill with a ring matrix by the Poland-based TESTER company, used by small and medium production plants.

The PD pellet mill (fig. 4) consists of three main units [Testmer Catalogue]: the working system of the pellet mill 1, a blade conditioner 3, a screw or blade feeder 4.
The working unit 1 of the pellet mill consists of a vertical ring matrix and two densification rolls. The matrix is driven by two electric motors M1 through belt gears 2. It is also possible to use a slippage control system of the transmission belts of the pellet mill. The pellet mill is equipped with a unit for the regulation of the length of pellets, an overload protection system for the drive unit (equipped with a fuse, in the form of a gudgeon pin, which is cut off if overload appears in the working system), and a system of automatic lubrication of roll bearings and main sleeve bearings. Pellet mills by Testmer also have the possibility of constant monitoring of the temperature of main bearings.

Feeder 4, driven by motor M3, enables volumetric control of efficiency and ensures even feeding of the mixture to conditioner 3. The blade feeder works with the mixer placed in the operating container, ensuring even feeding of the mixture to conditioner 3, which is equipped with a steam application system 5 that enables heat treatment of fodder (heating the mixture to max. 80°C). Conditioner 3 is driven by electric motor M2 through belt gear 6.

Fig. 4. Scheme of PD-15 type pellet mills with two Testmer motors [Testmer Catalogue]: 1-working system of the pellet mill, 2-belt gear transmitting drive from motors M1 to the shaft of the pellet mill, 3-conditioner, 4-feeder, 5-system of steam application to the conditioner, 6-belt gear transmitting drive from motor M2 to the shaft of the conditioner, M3 – electric motor driving the feeder [7]

The drive unit of feeder 4 can be equipped with a system of automatic control of the load of the main pellet mill unit and the temperature of the pelletsation process [Testmer Catalogue].

View of the ring working system of the PD-1 pellet mill by Testmer is shown in fig. 5.

Fig. 5. View of the ring working system of the PD-1 pellet mill; A-place where a set of tensometers for the measurement of matrix torque is stuck on
Fig. 6 shows a stand for performing the tests of the processes of pelletisation and briquetting of materials of plant origin (biomass).

The device consists of an immovable matrix 3 and two densification rolls 2. The set of densification rolls is driven by the shaft 9, bearing-supported in the shaft jacket 4, through the belt transmission 6 from the electric motor 8. The device is equipped with a feeder 1, whose position relative to the cone mounted in the upper part of the transmission shaft 9 can be continuously variably adjusted (continuously variable control of the quantity of the fed material). Technical data: power - 15 kW, speed of the set of densification rolls - 210 rpm, roll width - 102 mm, B, D-process temperature recorder, C- power recorder.

The schemes of the example flat matrices used in the universal pelletising and briquetting device shown in fig. 7.

Fig. 7. Example flat matrices [5]

2. Devices for the production of briquettes

Fig. 8 shows a scheme of the construction of a low efficiency screw briquette machine whose design was created in the Department of Agricultural and Food Techniques of Bialystok University of Technology [5].
The briquette machine consists of a densifying unit that is comprised of: feeding screw 1, densifying screw 2, working chamber 3, choke sleeve 4, cone pin 5 and forming matrix 6. Transitional matrix 7, briquette leads 8 and regulation of lead press 9 comprise the unit solidifying the formed briquette. The densifying unit is equipped with heating systems 10, 13 with temperature sensors 12. The heating system is protected with thermal insulation 11. The densifying system is driven by electric motor 26 through belt gear 19, crankshaft 18 mounted in main body 17. The drive system is coupled with the densifying system through fixing plates 14, setting plates 15, setting pins 16 and fixing frame 21. The whole of the device is mounted on base 22. The screw briquette machine is equipped with a working system jacket 24, gear jacket 23, control board 27 and charge 25.

The presented working system of a briquette machine with a low efficiency screw densifying system (approx. 100 kg/h) is characterized by a beneficial (in comparison with briquette machines available on the market) power demand.

Fig. 9 shows the view of briquettes made from spruce sawdust and spruce sawdust with a buckwheat hulls content obtained using the HD-3 screw briquette machine.
Fig. 9. Briquettes (from spruce sawdust, from spruce sawdust with a buckwheat hulls content) [5]

3. Conclusion

The paper presents selected devices to the producing heating pellets and briquettes (ecological solid fuel) from biomass. The presented suggestions are the result of many years of research of both the process of pelletisation and briquetisation and the design solutions of prototype universal pelletising and briquetting devices.

According to many authors research, the devices with a flat immovable matrix working system are a beneficial solution in the production of solid fuels in small- and medium-sized plants.

Research studies carried out by a team of authors and their collaborators allow to promote universal low-output devices for the pelletisation and briquetisation of materials of plant origin, which can produce solid ecological fuel (also from waste material) as well as industrial fodder on medium- and big-sized agricultural farms and in small- and medium-sized plants processing materials of plant origin.

References
7. Catalog of the TESTMER company.
8. LASKOWSKI J., 1989: Study concerning the pelletisation process of fodder mixtures. Published by Agricultural University of Lublin.

Santrauka

KIEETOJO KURO GAMYBOS IŠ BIOMASĖS ĖRENGINIAI. I DALIS

Vienas iš būdų konvertuoti biomases (išskaitant atliekų biomases) į energiją yra kieto kuro gamyba granulių arba briketų forma per slėgio aglomeraciją.

Straipsnyje pateikiama pasirinkta konstrukcijų ėrenginio, skirto gaminti šildymo granules ir briketus (ekologinės kietų kuras) iš biomases. Pateiktos konstrukcijos yra rezultatas daugelio metų tyrimų, nagrinėjant granuliuvo ir briketizavimo procesus, ir dizaino sprendimai granuliuvo ir briketizavimo ėrenginiuose. Šiuos tyrimus atlieka autorių ir bendradarbių komanda, jų bendradarbiavimas skatina visuotinę gamybą mažai sąnaudų reikalausančių ėrenginių, kurie gali gaminti kietą ekologinę kūrą ir įaugalnės kilmės atliekų, ir iš pašarų dideliuose ir vidutiniu dydžio žemės ūkio ūkiuose, perdirbant juos mažose ir vidutinėse įmonėse. Ėrenginiai su plokščia nekilnojamos matricos darbo sistema yra naudingas sprendimas kietojo kuro gamyboje mažose ir vidutinėse įmonėse.