Educational exhibition about flow of renewable energies in traditional maize culture in Galicia

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Abstract. *One of the main fields of interest of the authors of this article is the study of relationship between cultural heritage, sustainable development and renewable energies. As part of this work we are planning to adapt an ancient hydraulic flour mill to host an educational exhibition about traditional uses of renewable energies in the cycle of maize in Galicia (Spain), the first place in Europe where this cereal was introduced from America. The mill is in good condition and continues working, and will be itself an important part of the exhibition. The project consists of five parts, dealing with the diferent stages of cultivation, conservation, milling and baking of maize. The first part is about maize cultivation related to solar energy. The second part is about harvest, drying, storing and different energies involved in these processes. The third part is about flour mill, milling and hydraulic energy. The fourth part is about traditional wood oven, baking process and biomass energy employed. And the last part deals with energy performance of the whole process and conclusions. The exhibition is addressed to high school students, but could also be useful for other educational levels.*

Keywords. Educational Exhibition, Renewable Energy, Hydraulic Mill, Maize Culture.

1. Introduction

Renewable energies have been for many centuries the main source of power for all agricultural and industrial processes. Solar energy is still now the only source for plant growing and human feeding. And the need for agricultural production has been one of the major sources of cultural, scientific and architectural development. Many different types of buildings all over the world have been used for different agricultural works and adapted to take advantage of different energy sources.

In the case of Galicia, there has been a strong relationship between agriculture and certain renewable energies like hydraulic, wind and bio-mass, that has been the base of an environmentally friendly culture broken in the last decades by industrial development and contaminant energy sources like carbon an oil.

This article focuses in the particular case of maize cycle in Galicia, the agricultural processes, constructions and renewable energies employed.

The photographs, descriptions and technical data have been obtained in Beade (Vigo, Spain) from neighbors and relatives of the authors. Fig. 1 shows the traditional mill described in this article.

Figure 1. Mill and water channel

2. Cultivation of maize

2.1. Maize plant and field

Maize sowing in Galicia is made often in small fields (*eiras*), with a typical density of 2-3 plants per square meter. Sowing time is april-may and harvest is about september-october.

Figure 2. Maize field and plant

Many tools are used for cultivation with help of animals like oxes, Fig. 3 shows some examples of traditional tools.

Figure 3. Tools for maize cultivation (*arado* and *grade*)

2.2. Solar Energy Conversion

Growing of maize plants uses a high amount of energy that is obtained from direct and diffuse sunlight. We will try to estimate the average solar energy needed to produce a kilogram of dry grain of maize using real data from different sources:

1) Average production of maize in Pontevedra in kg/hectare: 10525. Source: Spanish Ministry of Agriculture 2007 report [6].
2) Daily average solar radiation in Nigrán, Pontevedra: 3,9 kwh/m2. Source: IES Escolas Proval Weather Station (Nigrán, Pontevedra) [7].
3) Maize sowing and harvest time: april-september (5 months) [1], these months concentrate about 60% of annual solar energy.
4) Energy of dry maize grain: 3000kcal/kg.

Using the above data we can calculate the percentage of solar energy that is stored into maize grain:

a) Solar energy received april-september: 925.71kwh/m2, that is
925.71*860.4kcal=796480kcal/m2, or
796480/1,0525kcal/kg=**756750.6kcal/kg**
b) Energy stored in maize grains per kilogram = **3000kcal/kg**
c) Performance: 3000/756750.6=**0,4%**

Another data should have been taken into account into this calculations to get a more accurate result. For example, human and animal work should be considered in terms of food consumption. If one person is needed to take care of one hectare of maize for 5 months and its food consumption is 2000kcal/day, the food consumption per maize kilogram yields:

2000*153/10000/1,0525=**29kcal/kg**

The same calculation should be performed for animal food consumption and machines fuel.

3. Harvest and storage

Harvest, storage and drying are the next operations that must be carried out when maize is fully developed. Ox chart is used to transport maize and it is stored in a typical building specially developed to keep grain dry and safe.

3.1. The Galician ox cart (*carro de bois*)

Ox cart was used as the universal mean of transportation in Galicia until oil-powered vehicles began displacing them. It is completely made of wood and iron and pulled by a couple of oxes called *parella*. Fig 4 show two images of ox charts.

Figure 4. Galician ox chart

3.2. The Galician grain storage (*hórreo*)

This type of building has been used for centuries to store grain [1]. Its special construction with many slots to let air flow through the walls can keep grain dry for a long time even in wet places like Galicia, and it can be considered one of the best examples of solar and wind energy use in agriculture. And its elevation over the terrain helps keep animals away from stored products. Fig. 5 shows an example of *hórreo* made of traditional materials like stone, wood and tile.

Figure 5. Grain storage (*hórreo*)

4. Milling

4.1. The Hydraulic Flour Mill

In Galicia there are many different types of flour mills according to the source of energy employed (wind, rivers, tide) and type of construction. The most common type is the water mill placed beside a small water stream with a small reservoir and a horizontal water channel (*levada*) that create a difference of level with the main water stream and can be converted into mechanical energy. Fig. 6 shows one example of this type of mill. Fig. 8 shows the lower part of the mill, with a wheel that converts water energy into circular movement. This energy is transmitted to the millstone (Fig. 7) by mechanical coupling.

Figure 6. Mill and water channel (*levada*)

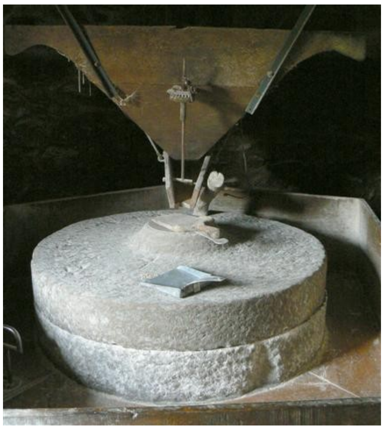

Figure 7. Millstone and grain supply

Figure 8. Mill wheel (*rodicio*)

4.2. The Milling process

Many hydraulic mills belong to a certain number of families that share the property and operation costs. Every family is assigned a number of hours of use per week.

The first step of milling is transportation of grain to the mill that can be made by hand, ox cart or mule, specially in places of difficult access. Fig. 9 shows arrival at the mill with a sack of grain.

Figure 9. Grain transportation to the mill

Milling can only be made when water flow and pressure provide energy enough to move the wheel and stone. Fig. 10 shows the water input at the upper part of the mill (*cubo*) that works as a buffer storage and creates the difference of level (potential energy). The image on the right shows the water output that is placed at the lower part of the mill. Fig. 11 shows the flow control of the mill (left) that opens or closes a valve to let water reach the wheel. The speed control (right) raises or lowers the upper stone of the mill, in such way that when the two stones are in close contact the mill stops completely.

Figure 10. Water input and output

Figure 11. Flow and speed controls

Milling process requires a precise control of the amount of grain that is allowed to get into the small space between stones. Too few grain could make upper stone increase speed and burn grain, and too much would stop the mill. Control mechanism is made of a few number of wood pieces that regulate the amount of grain according to the millstone speed, and is one of the best examples of mechanical regulator before Industrial Revolution in XVIII century. Fig. 12 shows some some pieces of this regulation system, like *moega*, *quenlla*, and *tarabelo*.

Fig. 13 shows flour collection and storage (in the same sack used for grain).

Figure 12. Grain supply regulator

Figure 13. Flour collection and end of milling

4.3. Hydraulic energy

In this section we will try to calculate the amount of hydraulic energy needed to mill one kilogram of grain. Numerical data have been obtained from real milling process in Beade (Vigo).

a) Height of water column=3.5m
b) water flow=10l/s or 10kg/s (density=1).
c) Power=9,8*3.5*10=343W=0,343kw
d) Time: 2h to mill 20kg of grain=0,1h/kg
e) energy=0,343kw*0,1h/kg=0,0343kwh/kg
f) 0,0343*860.4kcal/kg=**29.5kcal/kg**

5. Baking

5.1. The Traditional Wood Oven

Galician traditional houses had often their own wood oven, that could be inside the main house or as a separated construction. In other cases all the families in a village shared a common oven and used it by turns. Fig. 14 shows a typical oven ready to use.

Figure 14. Traditional Wood Oven

5.2. Kneading Process

Kneading is the first step of bread baking. It is done in a special tool called *artesa*, adding water, salt and a small portion of flour with yeast (*formento*) that must be stored until next baking. Fig. 15 shows three steps of the kneading process. After kneading bread mixture must be left in a hot place until raises (*leveda*). This operation can be made beside the oven while it is heating or in another warm place like the kitchen. Fig. 16 shows a piece of bread ready for baking.

Figure 15. Kneading process

Figure 16. Bread piece ready for baking

5.3. Oven Heating

One of the most important steps of baking is to achieve and maintain the right temperature inside the oven. A certain amount of wood must burn inside the oven until its inner wall changes its colour. This wall is made of a special type of brick that stores thermal energy and radiates it for a long time. The colour of these bricks reveals its temperature, and so there is no need for thermocouples or modern infrared thermometers. When the desired temperature is achieved wood is removed and bread can be placed inside the oven for baking. Fig. 17 shows different steps of oven heating.

Figure 17. Oven Heating

5.4. Bread Baking

The baking process is very simple: bread pieces are placed inside the hot oven and kept there until they are cooked. The oven door is closed with a wood door covered with mud to avoid heat leakages. The oven has no windows and the cooking time is based in previous experience. Mud drying can be used as a method of measurement, but it is not very accurate. Fig. 18 shows different steps of baking.Fig. 19 shows the final product, that is stored in the *artesa*.

Figure 18. Bread baking

Figure 19. Bread pieces in the *artesa*

5.5. Bio-mass energy

In this section we will try to calculate the energy consumption of the baking process. The source of energy in this case is wood or bio-mass. Experimental data show that each kilogram of maize flour yields about one kilogram of bread. The amount of wood used to heat the oven is 5 small bundles (*mollos*) of wood (about 5kg). The other data are obtained from different sources.

a) Wood energy: about 2500kcal/kg
b) Oven consumption: about 0,5kg wood per kilogram of bread.
c) energy per kilogram of bread:
0,5*2500kcal/kg=**1250kcal/kg**

6. Conclusions

The different agricultural processes of cycle of maize in Galicia, constructions and renewable energies employed have been studied in this article.

The materials contained in this article will be the starting point to make an educational exhibition about traditional uses of renewable energies in the cycle of maize in Galicia.

This exhibition will be installed in a traditional flour mill that will be itself an important part of the exhibition.

From the point of view of energy, calculations have been made to show the consumption of different type of renewable energies in every step of growing and processing of maize:

- solar energy:**756750.6kcal/kg**
- human (food) energy: **29kcal/kg**
- milling (hydraulic) energy:**29.5kcal/kg**
- baking (bio-mass) energy: **1250kcal/kg**
- total energy: **758059,1kcal/kg**
- maize energy: **3000kcal/kg**
- percentage: 3000/758059,1*100=**0,39%**

From the above calculations the following conclusions have been obtained:

Solar energy is the main source of energy used to produce one kilogram of maize or bread.

The cultivation process uses a high amount of terrain and collects solar energy with a very small performance, but at this time it is the only way of produce food for humans and animals.

In particular, baking is a very demanding process that consumes almost as much energy as that contained in the resulting product, but provides a system of conservation and facilitates human consumption of cereals.

Moreover, agricultural food production has been working well for many centuries, is environmentally friendly and allows sustainable development.

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