

SUSTAINABLE DISPOSAL OF WASTE FROM THE FLOWER INDUSTRY

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Abstract: Rapid urbanization around the world, exponential population growth and industrialization have made waste management a challenge that is increasing every day. Floral waste is a major problem because flowers play an important role in people's lives, beautifying interiors and landscapes and promoting human health. However, flowers are perishable and complex plant organisms that need to be handled and stored properly to maintain their value and quality. Despite the wide distribution of flower species, especially the marigold, only part of the plant is used, usually only the petals, while the larger part remains unused and becomes waste. Therefore, the question arises whether the residues that remain after the use of marigold flowers in various industries, especially in the production of marigold cream, can be used for energy production. For this reason, yellow and orange marigold biomass was used in this work. The basic physical and energetic properties were determined according to the given standards, namely the content of water, ash, coke, fixed carbon and volatile matter, as well as the upper and lower heating value and the content of C, H, N and S. The results obtained showed that for the sustainable disposal of biomass used for energy production, it is better to use yellow marigolds instead of orange ones, as they contain a greater amount of biomass. It was also proven that marigold biomass, with its high carbon content and good calorific value, is a good raw material for energy utilization.

Keywords: sustainable, marigold, energy production

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1. INTRODUCTION

There are many plant species on our planet that humans use for various purposes. Some plants are used for food, pharmaceutical, industrial, horticultural or cosmetic purposes. Of the large number of plant species, only a few hundred are of economic interest, and there are particularly few that can be used successfully in several areas. Marigold is precisely one of these species. *Calendula officinalis* L. is an annual, rarely biennial herbaceous plant (Bigdeli et al. 2023). It is native to the Mediterranean region, but its great importance and wide use have contributed to the spread of calendula throughout the world.

Because of its orange or yellow heads, it is one of the favorite decorative plant species in gardens around the world. As such, it began to be used in Indian and Arab cultures, after which its beauty was discovered by the ancient Egyptians and Greeks. Its name comes from the Latin word *Calendes*, which means the first day of the month. It was named so by the Romans because of the belief that the marigold blooms every month (Newman and Kirker 2016). Even the ancient Egyptians saw the benefits of this medicinal plant. It is a honey plant that produces pollen in addition to nectar. Given that they bloom from June to late autumn, it is of particular importance for bees, who find it difficult to find pollen at that time of the year. Marigold also has its contribution in gardening, where due to its characteristic smell it is used as a repellent and repels insects and other pests (Palihakkara 2016).

Although it does not play a major role in the kitchen, marigold is used in some cultures as a spice in various stews and as a decoration, as its bright colors enliven any plate. It is suitable for the production of edible colors for the food and cosmetics industry.

The use of marigold for medicinal purposes goes far back in history, when it was used as a remedy for jaundice, plague and some minor diseases such as wart (Heinrich et al. 2012). Apart from its beauty, its medicinal properties are the most frequently used properties of marigold. It is no coincidence that the marigold is also known as the "skin plant". It was given this nickname because it helps in the treatment of almost all skin diseases but is also effective for diseases of the nervous system, stomach, gall bladder, liver and veins (Oakeley et al. 2015).

Despite the widespread use of marigold, a large proportion of this plant remains unused and becomes waste. The problem of waste management is one of the most important problems facing mankind. It involves accurate sorting of waste, recycling and, where possible, utilizing the maximum number of valuable residues from waste to minimize the amount of unusable and unwanted substances (Lange 2021). Efficient use of waste is important for

protecting the environment and meeting the energy needs of the population (Kumar and Samadder 2017). Therefore, the question arises whether the residues that remain after the application of marigolds in various industries can be used for energy production.

The aim of this work is therefore to investigate the possibility of a sustainable disposal of the biomass of the flower industry, i.e. the use of the entire marigold plant (stems and leaves) after the petals have been used to produce marigold cream.

2. MATERIALS AND METHODS

The biomass of stems and leaves of yellow and orange marigold (*Calendula officinalis*) after the production of marigold cream was used for this study. The analyzes were performed on 50 yellow and 50 orange marigolds grown in external production in Croatia. The petals are used for the production of marigold cream. To capture the average characteristics of the population, no selection was made for flower size or plant height.

The investigation was divided into the determination of physical and energetic (ultimate and proximate analysis) properties.

The determination of the physical properties began with weighing the weight (mass) of the entire plant (excluding roots), the weight of the flowers and buds, the weight of the stem and the weight of the leaves, as well as measuring the length of the stem to determine the amount of residue that remains as waste after the flower has been used.

Energetic properties of stems and leaves of the two colors of marigolds was determined using standard methods. In the ultimate analysis the percentages of total carbon (C), hydrogen (H) and nitrogen (N) (HRN EN ISO 16948:2015) and the percentage of sulfur (S) (HRN EN ISO 16994:2015) were determined by the dry combustion method on a Vario, Macro CHNS analyzer (Elementar Analysensysteme GmbH, Langenselbold, Germany). The oxygen (O) content (HRN EN ISO 18123:2015) was determined by calculation.

Proximate analysis of the samples was performed according to standard methods and determined as follows: moisture content (HRN EN 18134-2:2017) in a laboratory dryer (INKO ST-40, Croatia) while coke (HRN EN ISO 18123:2015) and ash (HRN EN ISO 18122:2015) were determined in a muffle furnace (Nabertherm Controller B170, Lilienthal, Germany) The proportions of fixed carbon (HRN EN ISO 18123:2015) and volatile matter were determined by calculation. The higher heating value (HHV) was determined by the method HRN EN ISO 18125:2017 using an IKA C200 adiabatic calorimeter (IKA Analysentechnik GmbH, Staufen im Breisgau, Germany) while the lower heating value (LHV) was calculated.]

After collecting the laboratory research data, the data obtained was statistically processed using the SAS version 9.3 statistical program (SAS Institute, Cary, NC, USA).

3. RESULTS

Table 1 shows the results of measuring yellow and orange marigolds to determine the percentage that is treated as waste after the use of certain parts of the plant (flowers and buds) for cosmetic or medicinal purposes or, in this case, for the production of marigold cream. A comparison of the average mass of yellow and orange marigolds, taking into account the standard deviation, shows that the orange marigold has a greater mass. In orange coloured plants, 85% of the plant becomes biomass (stem 51%, leaves 34%). In the case of the yellow-coloured plants, as much as 90% of the plant is not used (stem 53%, leaves 37%). For the sustainable disposal of biomass that is not used for energy production, it is better to use the yellow marigold instead of the orange one, as it contains a larger amount of biomass.

Table 1 Average masses of yellow and orange colored marigolds

Samples	Mass (g)	
	Yellow marigold	Orange marigold
Entire plant	48.06±7.03	62.87±6.34
Stems	25.75±4.95	32.17±5.56
Leaves	18.03±3.26	23.82±5.76
Flowers	3.46±4.32	5.91±4.17
Buds	0.82±1.43	0.97±1.03

Table 2 shows the results of the proximate analysis of yellow and orange marigolds. The content of all analysed parameters was higher in orange marigolds than in yellow marigolds. A higher content of water (91.96%), ash (1.57%), coke (1.46%) and fixed carbon (0.11%) was found in the leaves, while a higher content of volatile matter

(8.07%) was found in the stem. Moisture is present in the fuel as a non-combustible component and has a direct effect on the calorific value of the biomass due to the amount of heat required to vaporise it and is usually between 40% and 95% in freshly collected biomass [Linn et al. \(2015\)](#), which is consistent with this study.

Table 2 Proximate analysis of yellow- and orange-colored marigolds

%				
	Yellow marigold		Orange marigold	
	Stems	Leaves	Stems	Leaves
Mositure	90.32±2.19	91.96±0.28	90.70±3.22	92.04±0.12
Ash	1.12±0.11	1.46±0.07	1.15±0.02	1.57±0.12
Coke	1.22±0.04	1.39±0.12	1.23±0.03	1.46±0.07
Fixed carbon	0.09±0.04	0.01±0.12	0.08±0.03	0.11±0.07
Volatile matter	8.02±0.04	5.98±0.12	8.07±0.03	6.50±0.07

Ash is undesirable in fuels as it lowers the calorific value and increases the transportation costs of the fuel. According to [Francescato et al. \(2008\)](#), the ash content in agricultural biomass is between 2 % and 25 %. The research results are consistent with the studies of [Matin et al. \(2019\)](#), which found that the average ash content in natural samples of *lisianthus* leaves is 1.50% and in the stems 1.30%.

The coke content represents the residue of dry distillation, and the higher its proportion, the better the quality of the fuel, while the fixed carbon content, in addition to ash, represents the solid residue after combustion or the release of volatile matter ([Jurišić et al. 2016](#)). Increasing the fixed carbon increases the heating value, which improves the quality of the biomass. Biomass usually contains a lower proportion of fixed carbon, which can be up to 20 % ([Bukarica 2018](#)), which is consistent with this study. During the combustion process, biomass decomposes into volatile gases and solid residues. If the concentration of volatiles is too high, biomass, unlike fossil fuels, is highly flammable even at lower temperatures, but this is an undesirable property due to the sudden release of energy at lower temperatures, so such fuels have a lower energy value ([Kontek 2016](#)). It is typical for biomass to have a high volatile matter content, even up to 80%, but such fuels have a lower heating value, which proves that marigold biomass can be disposed of by using it for energy production due to its low volatile matter content.

Table 3 shows the results of the ultimate analysis of yellow and orange marigolds. In the stem and leaves, the content of carbon (C), hydrogen (H) and nitrogen (N) was higher in orange marigolds, while the content of sulfur (S) and oxygen (O) was higher in yellow marigolds. Carbon (C) is the main and at the same time the most important element in all types of fuels. The carbon (C) content determines the fuel quality, and the quality of the fuel increases proportionally to the carbon content ([Vassilev et al. 2010](#)).

Table 3 Ultimate analysis of yellow and orange colored marigolds

%				
	Yellow marigold		Orange marigold	
	Stems	Leaves	Stems	Leaves
Carbon (C)	37.59±0.07	37.44±0.21	37.60±0.05	37.51±0.18
Hydrogen (H)	5.22±0.27	5.40±0.32	5.33±0.18	5.49±0.16
Nitrogen (N)	3.27±0.07	2.10±0.06	3.53±0.09	2.91±0.02
Sulfur (S)	0.78±0.31	1.35±0.23	0.67±0.22	1.46±0.13
Oxygen (O)	53.14±0.08	52.90±0.01	52.87±0.07	53.44±0.03

After carbon, hydrogen (H) is the second most important fuel component. Biomass has a lower nitrogen (N) and sulfur (S) content (compared to other fuels), which also means lower emissions of harmful gasses (NO_x and SO₂) during combustion. Nitrogen (N) is a non-combustible element and has a negative effect on the activity of the elements it is associated with, reducing the heating value of the fuel. Sulfur (S) is the least abundant element and is usually present in traces in biomass ([Matin et al. 2013](#)). According to the results ([Bogale 2017](#)), in the mixed biomass of flowers for the production of biofuel, the content of carbon (C) was 48.50%, hydrogen (H) 5.80%,

nitrogen (N) 3.62%, sulfur (S) 0.08% and oxygen (O) 42%, it can be said that by comparing the results obtained in terms of elemental analysis, marigold biomass is a suitable raw material for the production of biofuel regardless of the coloring due to the high carbon content.

Calorimetry is a method of measuring the amount of heat trapped or released during a physical or chemical process and is used to determine the calorific value of a fuel. The heat released during the combustion of a fuel with oxygen under standard conditions represents the calorific value, which is the most important characteristic of any fuel. The higher calorific value is the total energy recovered from the combustion of fuel, i.e. it represents the largest amount of energy that can be recovered from the combustion of fuel (McKendry 2002) and higher heating value is used in the design of energy systems of different sizes and is considered an extremely important parameter for the processes (Brandić et al. 2024).

From the data in **Table 4**, the higher heating value and lower heating value were slightly higher for the orange marigolds; the HHV averaged 14.63 MJ/kg and the LHV averaged 13.67 MJ/kg. For comparison, Matin et al. (2019) analyzed the biomass of lisianthus and obtained results where the HHV is around 16.50 MJ/kg for the stem and 14.50 MJ/kg for the leaves, which are slightly higher values than in this study.

Table 4 Higher HHV and lower LHV heating value of yellow and orange colored marigolds

MJ/kg				
	Yellow marigold		Orange marigold	
	Stems	Leaves	Stems	Leaves
HHV	14.60±0.12	14.59±0.05	14.61±0.16	14.64±0.02
LHV	13.42±0.09	13.47±0.08	13.45±0.11	13.48±0.08

The higher calorific value for barley straw is 16.41 MJ/kg and for oat straw 18.21 MJ/kg (Grubor et al. 2015). A comparison of marigolds and other plants shows that they have similar calorific values and that the leaves and stems are good raw materials for biofuel production.

4. CONCLUSION

After carrying out analyzes of the biomass of leaves and stems of orange and yellow marigolds, it can be concluded that although yellow marigolds have a larger mass after careless use in the cosmetics industry, the biomass of orange marigolds is greater. The analysis of the proximate and ultimate substances yielded results that allow the conclusion that marigold is a suitable raw material for energy use. The higher heating value of the samples tested is similar to that of other energy raw materials, which leads to the conclusion that marigold can be used as an energy raw material.

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