# Comparative analysis of nutritional properties of livestock feed from restaurant food waste and conventional agricultural feed sources

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**Abstract**: The negative effects of increasing food waste in the world are worrying for everyone. This research has examined the nutrients of food waste and compares it with agricultural products used in the livestock and poultry feed in order to manage the food waste produced in the restaurant with the approach of converting it into livestock feed. After designing and manufacturing food waste dryer, the food waste was collected from restaurants and kitchens and without any pre-treatment was subjected to heat treatment. The time of 210 minutes with three temperatures of 70°C, 55°C and 85°C were selected as experimental factors. The results showed that the amount of livestock feed protein produced was very close to agricultural products. Also, the energy metabolized by the livestock produced from food waste has increased with increasing heat treatment temperature that on average, animal feed produced from food waste provides 50 percent of the energy metabolized from animal feed obtained from agricultural products. Finally, it should be said that with exact evaluation of the amount of microbial and fungal contamination in the livestock feed, it can be used for livestock and poultry consumptions. The results of this study indicated that animal feed produced from food waste is one of the appropriate choices of animal feed.

**Keywords**: contamination, microbe, fungi, crude protein, feed

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## 1 Introduction

By 2050, food demand on a global scale is projected to increase by 60%-120% compared to the levels in 2005. Some reason for that are for example: population growth, rising incomes, and shifts in dietary preferences (Alexandratos and Bruinsma, 2012; Tilman et al., 2011). Increasing global income, changes diets from those which are more consisted of cereals to those which contain a higher amount of meat, dairy, and eggs (Delgado, 2003; Kastner et al., 2012; Delgado et al., 2020). Increasing demand for meat and dairy products is too important in the world, because their production needs more land, water, and

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energy than plant feeds (Gerbens-Leenes and Nonhebel, 2002; Pimentel and Pimentel, 2003; Wirsenius et al., 2010). Livestock production is the largest human use of land. Based on the 2011 analyses, 75% of all agricultural land is dedicated to animal production (Foley et al., 2011). The important issue that global system of food is faced with it, is that animal productions deliver fewer calories to the human food supply chain for calories they consume (Le Cotty and Dorin, 2012; Rask and Rask, 2011). Although, the yield of edible foods have increased over time (Naylor et al., 2005; Smil, 2000), the proportion of the livestock product calorie to the food calories on average is a still about 10% (Godfray et al., 2010; Rask and Rask, 2011). Totally, about 6 million tons of feed is generally consumed by producing animals that 72% of it is consumed by ruminants (i.e. cattle, goats, and sheep) (Mottet et al., 2017). About 65% ( about 1 billion tons) of the 1.57 billion tons of cereals and their by-products are consumed by pigs and poultry food (Mottet et al., 2017), but on the over hand along food supply chains, food moves from a primary producer to an end consumer progressing from harvesting, production, handling, processing, distribution and retailing to plate. During this progression, food is lost or wasted as a result of various technical, economic and/or societal reasons specific to each stage of the supply chain (Rajeh et al., 2021). It should be said that more than 1.3 billion tons of food is annually wasted each year (Gustavsson et al., 2011) which is 3 million tons more than the global consumption of all grains and by-products by pigs and poultry. One of the policies to ensure food security is to reduce the waste of agricultural products (Zakidizaji and Monjezi, 2018).

There are very different definitions of "food waste" (FW) in the world (Garcia-Garcia et al., 2015), but in this research the food wastes are defined as the difference between the amount of food produced and the total of all food used in any type of production use including food or non-food (Bellemare et al., 2017). FW sources can be based on the methods of using food from production to consumption, including food losses (food products lost during production), unavoidable FW (food lost during consumption) and avoidable FW (Products that may be eaten, but are lost during consumption) (Barthel et al., 2010). It is believed that both increase in the world population and its resulting wealth have led to a significant increase in production of food and waste (Surendra et al., 2015). Thi et al. (2015) reported that the total of FW in vitamin is about 5,743,056 tons per year that is 60% of the total municipal solid waste (MSW) FW per capita is estimated at about .06 kg per day (Thi et al., 2015). According to Zu Ermgassen et al. (2016), it is estimated that if the EU adapts regulated and concentrated systems for safe recycling of food waste in the livestock food similar to those successfully used in Japan and South Korea, this leads to 21.5 percentage reduction in land use (1.8 million hectares) to produced pork of the EU (Zu Ermgassen et al., 2016). In addition, if 39% of all EU food waste is used in pig feed, it can be replaced with 8.8 million tons of grains which currently fed to pigs is equal to the annual grain consumption of 70.3 million citizens of EU (FAO, 2014). In addition to the mentioned benefits, using food waste for livestock feed leads to recovering energy, nitrogen and phosphorus and there will be some minerals such as phosphorus (Hall and Hall, 1984; Scholz and Wellmer, 2013).

Separating protein meal production and livestock growth areas leads to protein deficiency in livestock feed in certain regions of the world. For example, Europe, where weather conditions aren't ideal to cultivate soybeans (e.g., Poor performance and longer growing times) should have almost imports. Two-thirds of the total protein required for feed (Kim et al., 2019). In China, soy self-sufficiency is predicated to decrease somehow, 16% until 2020 (Kim et al., 2019). In addition to being highly dependent on corn as a biofuel, it is also a food source for meat/ diary animals, because demand for protein, especially meat is increasing worldwide based on it (Mumm et al., 2014). Some corn (and soybeans) needed for livestock can be compensated by including food waste in the feed. Also, the integration of food waste can reduces the emission rate of current greenhouse gas (MMT CO2 3.7) from products which are directly considered for livestock feed (Lee and Willis, 2010). In 2010, 2.2 tons of food by-products produced in the UK food processes were transferred to the livestock feed (Barthel et al., 2010). According to the reports, in US 84% to 86.8% of food waste is dedicated to the livestock food part or ground-based programs from the process/products (Alliance, 2016; FWRA, 2016). MGM Grand company transferred food waste to a farm to fed livestock that it approximately saved 6000 to 8000 dollars per month in the livestock feed (Zanolli, 2012). Damron et al. (1965) found that the inclusion of a maximum of 10% of dry bakery product doesn't have a significant difference in the body weight and food conversion rate, compared to the poultry food. In addition, the results of the studies using fermented fish waste, different fruits and vegetables, fermented apple pulp and dried food waste support their use in meat diet (Bakshi et al., 2016; Hammoumi et al., 1998; Joshi et al., 2000; Wadhwa and Bakshi, 2013).

Also, such common animal feed for the not only supplied in terms of limitation, but also become more expensive over the years. On the other hand, the growing concern of weather changes which is expected to cause severe climate diversity (for example prolonged drought, severe winter storm and frequent flood among others) is likely to worsen food security situation due to its effect on agricultural food production systems (Groenewald et al., 2014).

The consumption of animal-based food contains considerable necessary amino acids (D'Mello, 2011; Food and Agricultural Organization, 2010; Organization and University, 2007) and also some important less consumption elements (such as; Ca, P, Zn, Fe, I, Se, and Vitamins A, D, E, B12) (Flachowsky, 2007; Reynolds et al., 2015). For example, Eriksson et al. (2015) showed that bread waste has the most potential to decline the emission of greenhouse gases, chicken, beef and bananas and lettuce have the least potential. These results show that food waste resources containing high energy and dry substances are more suitable for use as livestock food than resources with lower feed (Eriksson et al., 2015). In 1980 The use of food waste for livestock feed has severely reduced due to the outbreak of diseases (Leib et al., 2016). Also, since 2001, using uncooked food wastes as the livestock feed have been banned in EU due to the illegal feeding which was associated with the outbreak of snow fever in the UK. In contrast, some Asian countries have codified the policies and prepare the necessary infrastructure for thermal Processes to expand conversion of waste into livestock feed (Dou et al., 2018).

Finally, there is a valuable opportunity to recycle energy and nutrients in various sources of food waste that can be used as animal feed. The purpose of this article is to investigate the amount of nutrients and microbial and fungal contaminants in food waste before and after drying and compare it with agricultural products that are used as animal feed.

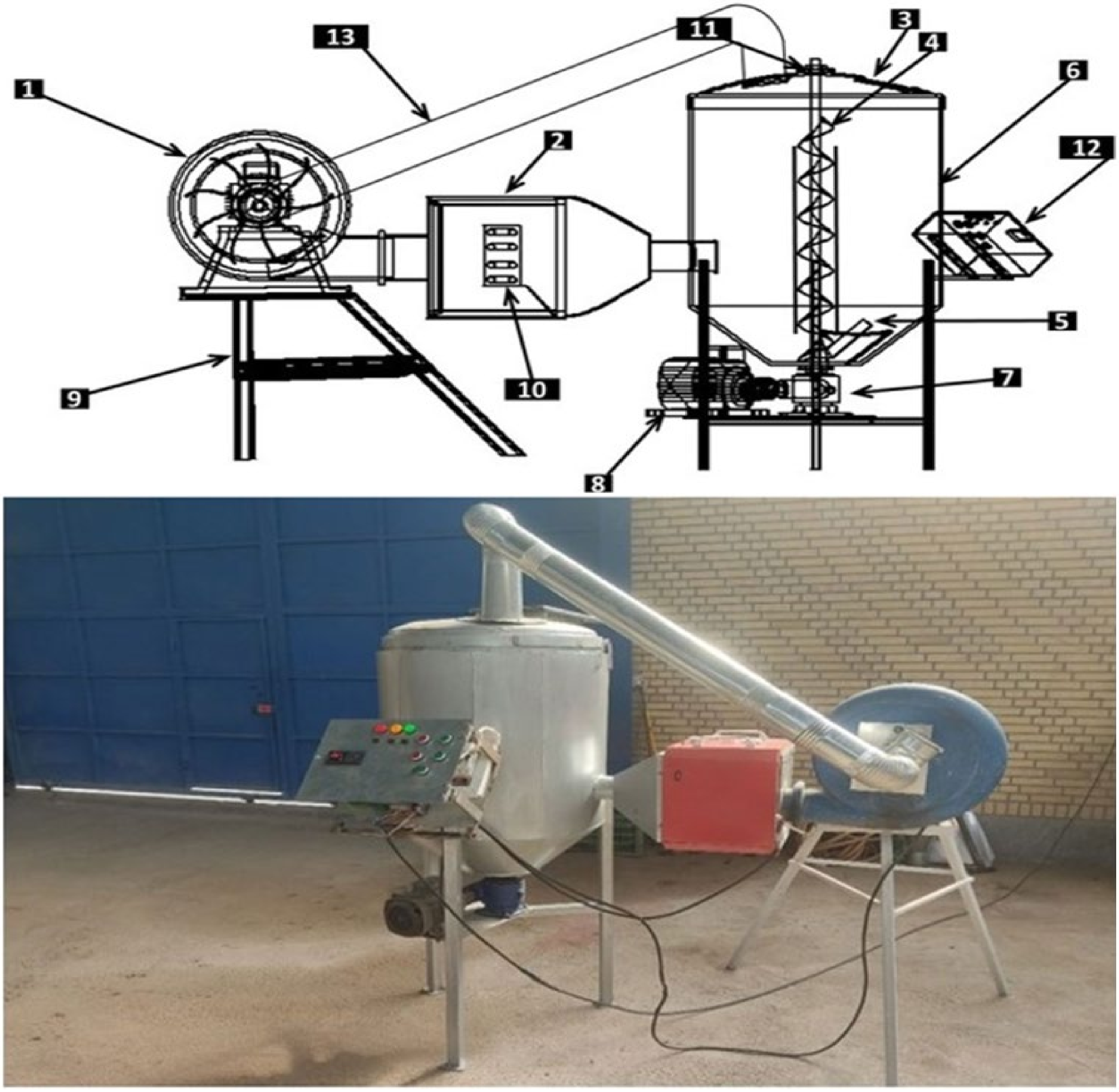
## 2 Materials and methods

After performing the calculations and designing, a reverse flow dryer system was constructed, in the Design and Construction Workshop, Department of Biosystem Mechanical Engineering, Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Iran (Figure 1). The reverse flow dryer was made up of four major parts including: reservoir, heating system, actuator, and electrical panel which consists of 13 parts in total (Rahmani et al., 2021).

Then, in order to determine and examine the amount of nutrient compositions, the restaurant food waste was collected and before and after thermal operation, it's quality properties were examined. The thermal operations of 55°C, 70°C, and 85°C were applied to food waste for 210 min. In this study no pre-treatment including crushing, squashing, and plating of waste performed to do thermal operation so that the obtained data would be closed to the reality.

### 2.1 Qualitative properties of waste

Qualitative properties which are studied in livestock and poultry feed included crude fat, crude fiber, ash, crude protein, moisture, and Nitrogen free extract (NFE). In this study in order to examine the qualitative properties after applying each thermal operation, some samples were selected for performing experiments and were transferred to the animal and poultry nutrition laboratory of faculty of animal sciences at the University of agricultural Sciences and Natural Resources. Table 1 shows the results related to calculated qualitative properties of crude protein, crude fiber, ash, moisture and NFE.




1-fan, 2-heater, 3-tank door, 4-helix, 5-blade, 6-main tank, 7-gearbox, 8-electromotor, 9-fan base, 10-element, 11-bearing, 12-electric panel, 13-air return pipe

Figure 1 Components of the reverse flow dryer

## 2.2 Crude fat measurement

A scale is used to measure a specific quantity of the sample, which is then subjected to drying at a temperature of 95°C-100°C for a duration of 5 hours. After cooling down, it is re-weighed (mL). Subsequently, the dried sample undergoes an extraction process using anhydrous ether for 4 hours at a rate of 5-6 drops per second. The extracted sample is dried for 30 seconds at 100°C and weighed after cooling ($m^2$). Finally, the percentage of fat is calculated."

## 2.3 Crude protein measurement

The specified amount of the gram homogenized sample is weighed in the digestion flask with a balance. 16.7 g of potassium sulfate, 0.01 g of anhydrous copper sulfate, 0.6 g of TiO2, and 20 mL of pure sulfuric acid are added to the sample. The digestion balloon is placed in the Kejdal oven. The oven is turned on at low heat for half an hour, and then the sample is subjected to high heat until it becomes colorless. After cooling the balloon, 250 mL of distilled water and a few drops of methyl red reagent are added to the balloon. The flask is connected to the distiller, and then the coolant valve is opened. In the receiving container, 60 mL of a 4% boric acid solution is added, along with a few drops of Tosiro reagent. The end of the refrigerant is placed inside the solution inside the container. Soda is added drop by drop to the balloon until the contents of the balloon are completely titrated. The distiller is turned on until 150 mL of the distilled solution is collected. Then, the receiving balloon is removed from the refrigerant, and the heat is turned off. The distillate is titrated with sulfuric acid or hydrochloric acid until it turns purple-blue.

Nitrogen percentage titration by hydrochloric acid:

Nitrogen percentage titration = (M acid)×(mL acid)×1.4

Sample nitrogen percentage (titration by sulfuric acid):

Sample nitrogen percentage = (M acid)×(2)×(mL acid)×1.4

(M acid molarity of sulfuric acid or hydrochloric acid used, Ml acid volume of acid used)

To calculate protein, multiply the amount of nitrogen by 5.95.

**2.4 Crude fiber measurement**

One gram of the ground sample (M) is weighed and poured into the jar. The sample is defatted in ethyl ether. The valves of the device are opened and the cold water of the coolant is turned on. Then the mug is placed on the hot extractor. Reagent 1 is heated to 90°C and poured onto the sample up to the middle mark. The temperature of the heater is set to the maximum until the sample boils, and then the temperature of the heater is reduced, and thirty minutes are taken. If the sample foams, two to three drops of octanol are added from above to the sample. After thirty minutes, the heater is turned off, and first, the vacuum valve is opened, and then the vacuum pump is turned on to remove all the acid. The column is washed two to three times with boiling water, and each time, the hot water is removed from the system using a vacuum. All the above operations are repeated with Reagent 2, and at the end, it is washed again with hot water. The mug is removed from the Hot extractor mode and placed in the Cold extractor mode, and the contents of the mug are washed with stan. The mug is removed from the cold extractor and left in the open air for 5-10 minutes, and then it is placed in the oven at 130°C for 2 hours to dry completely. Then the mug is cooled in a desiccator for half an hour and weighed (M1). The weighed crucible is placed in a 550°C oven for 3 hours. After three hours, the oven temperature is lowered to 100. Then the crucible is removed from the oven and placed in a desiccator and then weighed (M2).

$$Fiber\ percentage = \frac{(M_1 - M_2)}{(M)} \times 100$$

*The unit of M is in grams.

**2.5 Ash measurement**

In order to determine the total ash, we pour some dried sample into a ceramic container and then weigh it. The sample and the ceramic container are placed in the furnace for 8 hours at a temperature of 550°C. After the heat treatment, the sample is placed in a desiccator to cool down, then the final weight is also recorded. It should be noted that the weight of the ceramic container without sample is also recorded. In order to calculate the amount of ash:

$$total\ ash = \frac{Weight\ of\ bush\ and\ ash - plant\ weight}{weight\ of\ the\ prototype} \times 100$$

Also, in order to calculate the metabolized energy in animal food produced from food waste due to the high volume of rice in the collected food waste, Equation 1 was used ( National ResearchCouncil [NRC], 1994).

$$MEn = 46.7 \times DM - 46.7 \times ash - 69.55 \times CP + 42.95 \times EE - 81.95 \times cf \quad (1)$$

* DM Dry Matter , CP Crud Protein , EE Ether Extract , CF Crude Fiber

* All of units are in percentage

Qualitative properties of corn, barley, wheat and rice are the main resources of animals and poultry feed in the world ( NRC, 1994) . Table 2 shows the qualitative properties of these products.

**2.6 Counting mold and yeast**

Twenty-five g of food sample is added to 225 mL of sterile peptone water. The above solution is homogenized by Stomaker for 2 minutes. 0.01 and 0.001 dilutions are obtained from this solution. 0.1 g of solutions are cultivated in the culture medium. After putting the lid on the samples, 15 minutes are allowed for the sample to be completely absorbed by the environment. The samples are kept in a greenhouse at a temperature of 25°C for 5 days. On the 5th day, the number of mold and yeast colonies and other colonies are counted, and then their amount is calculated using the following Equation 2:

$$\frac{cfu}{gr} = \frac{\sum a}{v \times [n1 + 0.1 \times n2)] \times d} \quad (2)$$

Where, $\sum a$ is total number of counted colonies, $v$ is the volume of the inoculated sample, $n_1$ is the number of plates counted in the first dilution, $n_2$ is the number of plates counted in the second dilution, $d$ is the dilution coefficient according to the first dilution selected.

**2.7 The general calculation method of the form**

The work surface should be sterilized with 70% alcohol before starting. Sterilize the sample lid, then open the sample lid with the help of sterile scissors next to the flame. Using a sterile spoon, weigh 10 grams of the sample into a sterile beaker and pour it into 100 mL of phosphate buffer. Then take one milliliter of the solution with a sterile pit and pour it into 9 milliliters of phosphate buffer and continue this until the dilution reaches 0.001. For each dilution, consider three tubes containing lauryl sulfate tryptone L.S.T along with a Durham tube and three tubes containing Brilliant Green Brass B.G.B medium along with a Durham tube. Then add one milliliter of the desired dilution to each tube using a sterile pipette. Place all tubes in an incubator at 337°C-335°C for 48 hours. After 24 hours, check the tubes and take them out of the incubator if there is gas, otherwise, let them stay for another 24 hours. Separate the B.G.B tubes that are cloudy and determine the total number of coliforms using the MPN method rules.

## 3 Results and discussion

Comparison between qualitative properties of the waste and agricultural products as it can be seen in Table 2, the percentage of agricultural products protein is reported between 9.55-13.22, while food waste protein percentage is reported between 7.64 - 11.31 in the Table 1, which shows that the amount of food waste protein is closed to agricultural products used in animal feed. While the amount of fat reported for waste has a considerable distance corn, but it is very close to the amount of rice fat. Also, the most amount of fiber reported for waste is evaluated at 79%, while the lowest amount of fiber among agricultural products has been reported for corn. Finally, the amount of ME calculated for food waste is reported by comparing the amount of this component for food waste and agricultural products, it is found that there is a very significant difference between the amount calculated for waste and all agricultural products, but performing thermal operations has increased the metabolized energy level so that the temperature of 85°C had the highest energy level.

**Table 1 Qualitative properties of the kitchen food waste in the two modes, before and after the thermal operation**

| Time(min) | Temperature(°C) | CP% | EE% | FIBR% | ASH% | Moisture% | NFE | ME(Kcal×Kg$^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| 0 | First sample | 7.64 | 0.79 | 0.43 | 2.39 | 60.34 | 88.75 | 1207.925 |
| 210 | 55 | 8.02 | 0.47 | 0.58 | 2.79 | 50.21 | 88.14 | 1609.8805 |
| 210 | 70 | 11.31 | 0.19 | 0.44 | 2.43 | 47 | 85.63 | 1547.199 |
| 210 | 85 | 9.37 | 0.39 | 0.41 | 2.73 | 44.07 | 87.1 | 1815.9895 |

Note: *The value of qualitative properties of protein fiber, fat are calculated in terms of dry substances

NFE=100-(CP+CF+EE+Ash).

**Table 2 Qualitative properties of ground corn and soybean (NRC, 1994) examining microbial contamination**

| Crop | CP | EE | FIBR | Moisture | DM | ME(Kcal×Kg$^{-1}$) |
|---|---|---|---|---|---|---|
| Corn | 9.55% | 4.27% | 2.47% | 11.00% | 89 | 3350 |
| Barley | 12.36% | 2.02% | 6.18% | 11.00% | 89 | 2640 |
| Wheat | 13.22% | 2.87% | 3.45% | 13.00% | 87 | 2900 |
| Rice | 9.78% | 0.79% | 11.01% | 11.00% | 89 | 2990 |

Mycotoxins are produced by fungi and mold that are present in food. They can cause problem in humans or livestock and poultry. Smith and Hamilton (1970) have reported that the existence of 2.5 (mg kg$^{-1}$) of aflatoxin in the chicken feed can decrease growth.

The first evidence of bacterial contamination in the US was in 1948, when salmonella was detected in poultry feed (Edwards et al., 1948). Due to the ability of food to produce and transfer salmonella infection, food contamination regulations have been in some countries for several decades (Davies et al., 2004). However, Salmonella can be easily inactivated by processing the substances at 55°C, for 1 hour or at 60°C for 15 to 20 minutes (Sancho et al., 2004).

According to Table 3, the values reported in the food waste has the ability to grow and multiply in animal feed and cause infection if not planned. So, after thermal operations you should consider that the produced animal food should be consumed as soon as possible. It is suggested that according to the effect of temperature in removing bacteria and other methods of long-term storage, a study should be done along this research.

**Table 3 The rate of fungal and microbial contamination**

| Durability | | | |
|---|---|---|---|
| Time(min) | Temperature (˚C) | Mold and fermentative | Microbe |
| 0 | First Sample | 1.76×1000 | 12 |
| 210 | 55 | 3.9×10000 | 14 |
| 210 | 70 | 1.67×1000 | 18 |
| 210 | 85 | 3.6×10000 | 14 |

Note: *The rate of shelf life is based on number per gram.

## 4 Conclusion

Considering the importance of animal feed in ensuring the security of the food chain, this research provides a suitable platform for increasing the methods of providing animal feed. The results of this study indicated that animal feed produced from food waste is one of the appropriate choices of animal feed due to the high amount of protein produced from food waste and also their potential for animal feed in metabolized energy. However, the evaluation of bacteria and fungi showed that the control of microbial contamination and the complete process of conversion and timely consumption of animal feed after production are among the most important issues that should always be carefully evaluated in the conservation process.

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