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A review on orange pulp: quantity, composition and uses

Una revisión sobre la pulpa de naranja: cantidad, composición y usos

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ABSTRACT

The cultivation of citrus fruits such as oranges, lemons, tangerines, lime and others is an important agricultural activity in Mexico, and orange is the main crop of all processed citrus fruits (80 %). The by-product of the juice industry and of small shops selling juice is the waste or pulp of citrus fruits, which is composed of the husk, bagasse, seeds, juice, oils and fruit waste. This by-product can be used as: source of dietary fiber, use in animal feed (fresh, fermented, dehydrated, molasses, cake), bed, dextran and fructose production, and compost; however, much goes to the landfill. When dehydrating the pulp of citrus sun has a yield of 23.9 %.

Keywords: citrus, agricultural, animals, waste.

RESUMEN

En México, el cultivo de cítricos como la naranja, el limón, mandarina, lima, entre otros, es una actividad agrícola importante. La naranja es el principal cítrico que se procesa (80 %). El subproducto de la industria de jugos y pequeños comercios de venta de jugo es el desecho o pulpa de cítricos, el cual está integrado por la cáscara, bagazo, semilla, jugo, aceites y frutos de desecho. Este subproducto se puede utilizar para alimentación animal (fresco, fermentado, deshidratado, melaza, y torta), fuente de fibra dietética, uso en cama, composta, producción de dextrano y fructosa; sin embargo, mucho se va al relleno sanitario. La deshidratación de pulpa de cítricos al sol tiene un rendimiento de 23.9 %.

Palabras clave: cítricos, agricultura, animal, desecho.

INTRODUCTION

By-products of plant origin and agricultural wastes have increased exponentially in recent decades in Mexico; these have been deposited in landfills or incinerated to be transformed into greenhouse gases, such as methane, carbon dioxide, nitrogen oxides, sulfur oxides and others (Raj and Antil, 2011). In response to this, an important part of biotechnologists around the world focused their research on the use and use of agroindustrial waste for the production of useful compounds as inputs of other industrial processes. At the beginning the priority was focused on the generation of products with added value, years later it was added to use the waste to reduce the environmental impact that it causes, and as of this century the priority is oriented to the production of bioenergetics and the development of new feed formulations for animals (Saval, 2012).

In Mexico, in 2006, 75.7 million tons of dry matter from 20 crops were produced, of which 60.1 million tons correspond to primary waste, obtained at the time of harvest, among which are: corn leaves and stems, sorghum stems and pods, sugarcane tips and leaves, wheat straw, barley and bean straw; as well as cotton shell. The rest, 15.6 million tons correspond to secondary waste obtained from post-harvest processing, among which are: sugarcane bagasse, cobs and olotes, maguey or agave bagasse; as well as coffee pulp.
Some data that serve to get an idea of the volume of waste generated by different types of industries, are the following: the beer industry uses only 8 % of the components of the grain, the rest 92 %, is a waste; the palm oil industry uses 9 %, the remaining 91% is a residue; the coffee industry uses 9.5 %, the remaining 90.5 % is a waste and the paper industry uses less than 30 %, the rest is a waste (Valdez-Vázquez *et al*., 2010).

Citrus is one of the most important activities in agriculture, and in Mexico it represents an option for a large number of producers, mainly from tropical areas in the states of Veracruz, San Luis Potosí and Tabasco; while another important percentage is distributed in Nuevo León, Tamaulipas, Guerrero and Sonora; some of which participate in the export of this product (Nieto, 1998). Production yields range between 9 and 35 tons per hectare.
The countries with the best yields are the United States and Cuba, as a result of the good agroclimatological conditions that prevail and the technology used. Among the citrus fruits, orange (Citrus sinensis) stands out, which covers about 71.4% of that sector (Del Rosal, 2003). When citrus fruits are processed to obtain juice and other products, about 50% of the total mass of the fruit is waste (peel, skin and seeds) or citrus pulp, which is used in the feeding of cattle and pigs (Jiménez *et al*., 2012).

LITERATURE REVIEW

The residue derived from the extraction of the juice is called citrus pulp, and is formed by the peel, bagasse, and seeds, along with a small amount of juice, oils and waste fruits. Approximately 45 to 60 % of the total fruit weight is waste or citrus pulp (60-65% peel, 30.4% pulp and 0-10% seeds); which is obtained from juice processing plants or from local juice stores. Citrus pulp consists mainly of orange and grapefruit; although sometimes lemon, but it is less desirable (Gaztambide, 1986; Flores, 1991; Bueno *et al*., 2002; Viuda *et al*., 2008; Romero, 2010).

Every year about 20 million tons of citrus are used in the world for the production of juices and concentrates, this figure represents 40% of the world production of citrus. Orange is the main of all processed citrus fruits (80%), followed by grapefruit (9%), lemons (6%) and tangerines (5%) (FAO 1989).

Orange availability in Nayarit, Mexico.

In Nayarit state, orange comes from Veracruz (in October), Tamaulipas (in May), Sonora (in July) and Yucatán (in August); 400 to 800 tons per month enter, approximately between 13 and 26 tons/day; those that are distributed throughout the state and in Puerto Vallarta, Jalisco. For a liter (1.1 kg) of orange juice 2.2 kg of orange are required, so 50 % is waste, calculating that there is a daily availability of between 7 and 13 tons, which go to the landfill of the different municipalities of Nayarit and Puerto Vallarta, Jalisco. For the Tepic and Xalisco area it is estimated that they are between 5 and 7 tons/day (Tepic Supply Market, 2017; Tepic stalls and stalls of natural juices, 2017).

Derivatives of orange and other citrus

The main derivatives of citrus fruits are the following: a) essential oils: they are used in the perfume, candy, food and pharmaceutical industries; b) juice: due to the high nutrient content, it is marketed as fresh, pasteurized, concentrated, pulpy and clarified juice; as well as powder concentrate; from a ton of orange, for example, 20 gallons of concentrate at 65 °Brix are obtained; 1.95 kg of essential oil, and 100 kg of livestock feed; c) jams and jellies, and d) dehydrated peel for livestock feed and for obtaining pectins (SARH and BANCOMEXT, 1995).

The chemical composition of orange pulp

Fresh orange pulp is rich in carbohydrates, high in water and low in protein, fat and minerals; the orange rind is rich in protein, fat and minerals. In addition, the bark and pulp are high in vitamins A, B and C; as seen in table 1 (Gaztambide, 1986). Orange pulp contains 27.3 mg/100 g of calcium, 8.64 mg/100 g of magnesium, 0.38 mg/100 g of Zinc and 16.3 mg/100 g of ascorbic acid (Rincón *et al*., 2005).

Table 1.- The chemical composition of fresh orange pulp

Product	Composition (%)					
	Water	Minerals	Proteins	Carbohydrates nitrogen-free extract	Fiber	Fat
Fresh pulp	80	0.67	1.7	15.2	1.61	0.75
Bark	30	3.65	6.26	47.5	10.7	1.80

Gaztambide, 1986.

In a study conducted by Coppo and Mussart (2006), with waste from the toy industry, they found that it was made up of: orange bagasse (60%), grapefruit (20%), tangerine (10%) and lemon (10%); and reported that it contained 7.6% crude protein, 17.7% crude fiber, 4.5% ethereal extract, 65.7% non-nitrogen extract and 4.5% ash (0.17% phosphorus, 0.54% calcium, 0.03% sodium, 0.50% potassium, 725 mg / kg magnesium, 15 mg / kg manganese, 78 mg / kg zinc, 83 mg / kg iron and 15 mg / kg copper); with 3.62 Mcal / kg dry matter (15.5% of gross energy).

Table 2.- Chemical composition of orange by-products with different processes

Product	MS	PB	FB	Ash	EE	ELN	Calcium	Phosphorus
Whole fresh oranges	12.8	7.8	9.4	4.7	1.6	76.5	0.47	0.23
Fresh Orange Pulp	16.1	6.8	6.2	3.7	1.9	81.4	1.3	0.12
Orange pulp silage	19.6	7.7	14.3	5.1	2.6	70.3	1.38	0.10
Dried citrus pulp	91.8	8.0	11.4	5.5	3.9	71.1	-	-
Citrus Molasses	85	5.8	0.0	6.6	0.3	87.3	1.13	0.08
Citrus Seed Flour	85	40	8.8	7.0	6.7	37.5	-	-

Nutrient composition on dry basis and in%. MS (dry matter). PB (crude protein). FB (gross fiber). EE (Ethereal Extract). ELN (Nitrogen Free Extract) (Gohl, 1975).

The palatability of citrus pulp is good, it has a high digestibility of 85 % and an energy value similar to that of barley (2.67 Mcal of metabolizable energy); its ruminal fermentation is typically acetic. Among the characteristics of the citrus pulp protein, the high solubility (35-40 %), an effective degradability of 65% and a degradation rate of 6% per hour stand out. The intestinal digestibility of the protein that escapes ruminal degradation is of the order of 85 % (FEDNA, 2004.)

In an investigation, the dehydrated moist pulp at a temperature of 90 °C, without removing the seeds or extracting the molasses; The dry residue was found to contain 8.1 % crude protein, 11 % crude fiber, 73 % nitrogen-free extract, and 14 % sugar. Half of the protein was true protein, but low in lysine. The total digestible average and digestible energy of citrus pulp calculated by difference was approximately 80% and 3,503 kcal/kg, respectively (Bhattacharya and Harb 1973).
Dry pulp paste contains amino acids, such as: lysine 30.8, histidine 17.4, arginine 45.6, aspartic acid 90.7, threonine 29.6, serine 36.4, glutamic acid 82.8, proline 89.7, alanine 38.7, valine 37.1, methionine 8.31, isoleucine 48.5, tyrosine 29.6 and phenylalanine 28.9 mg/g of nitrogen (Bhattacharya and Harb, 1973).

Table 3 shows the chemical composition, digestibility and fiber of the orange pulp, and in table 4 we find the chemical composition in different presentations of orange waste.

Table 3. Comparison of the chemical composition and in vitro digestibility of DM (%) of fresh orange residue and sorghum grain

Indicator	Fresh Orange Residue	Sorghum grain
Dry material	21.9	90.2
Crude protein	6.0	11.2
Raw fiber	16.2	4.3
Ethereal extract	2.4	3.2
Nitrogen free extract	72.2	76.4
Ashes	3.2	4.9
Neutral detergent fiber	22.7	45.2
Acid detergent fiber	17.1	26.4
Cellulose	11.7	13.1
Hemicellulose	18.0	9.7
Lignin	1.7	2.1
DIVMS	72.3	68.0
MS (MJ/kg DM)	10.9	10.0

DIVMS = in vitro digestibility of MS (dry matter). Villanueva *et al*. (2013).

Table 4.- Composition of orange flour

Determination	Composition (%)
pH	4.29 ± 0.15
Ashes	3.33 ± 0.74
Crude protein	5.63 ± 0.14
Ethereal extract	0.59 ± 0.08
Total dietary fiber	39.5 ± 2.08
Soluble dietary fiber	20.1 ± 1.71
Insoluble dietary fiber	19.0 ± 1.34

(Jiménez *et al.,* 2012).

Uses of orange Waste

Orange waste has many forms of use, which are explained superficially below; however, many tons still go to the landfill.

1). Source of dietary fiber. Jiménez *et al*. (2012) indicated that orange residues are an excellent source of fiber, since they possess sufficient amounts both soluble and insoluble; with positive effect on the growth of beneficial bacteria and negative on that of pathogens; In addition, being a good source of acetic acid and ascorbic acid, which is necessary to maintain good intestinal health.

2). Fresh or fermented the origin of the orange pulp, are the juicers, stationary or street shops that regularly deliver it in black bags. It is recommended to keep them in the same bags for fermentation; getting a brown product and pleasant smell. The appearance of the peel is as if it were cooked. Fermented orange pulp is offered as a supplement to grazing sheep; the quantity varies according to the quality of the grazing and the productive stage; for example, sheep in early pregnancy and with grazing regulate quality; it can be helped with 500 g of orange pulp per head/day, in lactating sheep with regular grazing quality; It can be given from 1 to 3 kg per head/day; This greatly reduces the concentrate offered to the lactating sheep.
In some farms another type of supplement has been completely removed, only the orange waste and grazing are offered. Care must be taken not to serve a shell that has fungal contamination or has an unpleasant smell (Soto and Delgado, 2014). When the changes in the bromatological characteristics of the fresh orange waste stored in piles outdoors during the month of May (temperatures that varied from 32 to 38 ° C and a relative humidity of 75 to 80%) were evaluated, taking three representative samples daily, at a depth of 30 to 40 cm, in a completely random design; it was observed that the dry matter increased (p <0.01) from 210 to 310 g / kg during the storage period; The increase in dry matter was 10% (21 to 31%), indicating that it could be due to a loss of moisture due to runoff and dehydration. The crude protein content remained relatively constant (p> 0.05) during days 1 to 5 (of 9%); while during days 6 and 7 the values were higher (of 14 and 17%; p <0.01). The contents of organic matter, neutral detergent fiber, acid detergent fiber, hemicellulose, cellulose, lignin and ashes were not modified (p> 0.05) during storage days; Therefore, the fresh orange waste stored in piles for up to 7 days does not show significant variations in the bromatological content that compromise the use in the feeding of ruminants (González-Reyna *et al*., 2013).

3). Mixed silage for many reasons, silage is the best method of forage conservation. By-products of the food industry can be used by making mixed silages. They are called that, because some products are added to raise the value of the silage (figure 1). The preparation consists in diluting 600 g of urea in 60 liters of water; then add 50 kg of molasses in the water. Subsequently, place a thick layer of stubble under the container or silo; then a layer of orange peel (crushed). Then a layer of water with molasses and urea to moisten the orange and stubble; continue to layer by layer in the same way, ramming to compact each layer. Finally, cover perfectly with black plastic for silos, to avoid the entrance of air and rainwater. In 25 days the silage is ready to be offered to the animals.

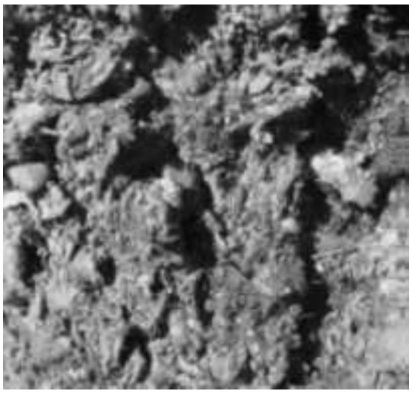

Figure 1. Enriched orange silage, image of Supreme Lamb

Silage pulp is an alternative for feeding cattle during the dry season, especially in arid areas; if microorganisms are added to the silage, it is possible to increase the protein content from 4.5 to 18 % (UNPG, 2012). Ammonia can also be used easily; the simplest method is to place the residue in a long sleeve of polyethylene and introduce ammonia gas at one end (Gohl, 1975).

4). Dehydrated pulp. Dehydrated pulp in the sun is less bulky, retains better and is easier to use; it should be given in a balanced ration with protein and mineral concentrates. The ground waste looks a lot like ground corn with a pleasant smell, although it lacks toxic effects; in large quantities it has a laxative effect. When it is not possible to dry it, it can be used fresh or ensiled in barrels or drums, where it can remain for up to eight months without deterioration. Intakes of up to 40 kg per day have been recorded without the least harmful effect, except for the possible danger that the whole fruit may get stuck in the esophagus; therefore, it is better to cut the fruits before supplying them to cattle (Gaztambide, 1986).

5). Oil cake. Sometimes the seeds are collected separately in the toy industry and undergo an oil extraction process; the resulting oil cake is usually called citrus seed meal, which contains 40 % crude protein; however, it contains a toxic substance, limonine, for pigs and poultry; therefore, the use in these animal species is not recommended (Gohl, 1975; Gohl, 1982; Orozco, 2015).

6). Citrus molasses. Citrus molasses is obtained when the orange pulp is pressed before spreading in the yard; molasses contains 9 to 15% solids, of which 60 to 75% correspond to sugars; it is usually a thick and viscous liquid, of a dark brown to almost black color, with a very bitter taste due to the presence of naringin, a flavonoid; however, it can be used as sugarcane molasses, at a rate of 5 to 10 % in diets (Gohl, 1975).

7). Compost In one study, physical, chemical characteristics were determined, and phytotoxicity bioassays of composted residues of wheat straw, cane bagasse and orange peel were performed; because they are in great availability in the regions of Oaxaca, Mexico. The three substrates showed good moisture release (34.2%), total porous space greater than 85%, low apparent densities (0.1 g/cm-3) and real densities (1.31 g / cm^{-3}); pH increases from acid to neutral. Wheat straw compost showed the highest concentrations of nitrogen (0.79%), phosphorus (3.0%) and potassium (0.54%); a significantly higher electrical conductivity (6.65 dS m^{-1}) and germination index greater than 120 in broccoli seeds (López *et al*., 2015).

8). Bed. Edible mushroom growers (fungi or mushrooms) generally use straws (wheat straw, barley straw, rice straw, orange peel, coffee pulp, cotton stalks, grape distillery residues) and at the end of the fungal growth period. Straw fiber has been widely solubilized, so it is possible that animals consume this straw and take advantage of it more efficiently, since fungi solubilize lignin bonds and improve the digestibility of fiber and lignocellulosic components of the cell wall (González, 2010).

9). Dextran and fructose production. In Colombia at the laboratory level for the production of dextran and fructose from orange peel, pineapple and paneled cane cachaza, using a strain of Leuconostoc mesenteroides. The authors determined its characteristics and concluded that the dextrose obtained is a technical grade and can be used as a thickener in the food industry, or as a flocculant for wastewater treatment (Rodríguez and Hansen, 2007).

Use in animal Feed

Citrus waste is a valuable food, both fresh and dry. The fresh pulp is pleasant to the palate and the cattle eat it with pleasure; but it must be provided to the animals immediately arriving at the farm, as it decomposes rapidly. It is recommended to offer it chopped, as animals do not waste any product; although they also eat it in halves. Dehydrated citrus pulp is lighter, bulky (160 kg/m^3), contains much less moisture and is less palatable; however, cattle eat it without difficulty, especially when mixed with other ingredients. In pigs there are good results in weight gain and profitability (Gaztambide, 1986; Ángeles and Cortés, 2009). The international food number is 4-01-237 (Church and Pond, 1990).

Citrus pulp does not alter the taste of milk. Fattening or dairy cattle easily consume citrus pulp once they have adapted to consumption. In milk cattle, a level of 30 % citrus pulp in the diet is recommended, since it increases milk production by 0.5 kg/day. In pigs, the usual inclusion levels are usually between 10-15 % and a maximum of 20 % on a dry basis, higher inclusion levels can penalize productive yields. In beef cattle with the use of 60 % citrus pulp in the diet, an average daily gain of 940.2 ± 195.2 g/day can be obtained (Flores, 1991; Gaztambide, 1986; Viuda *et al*., 2008; Bueno *et al*., 2002; Romero, 2010).

Orange pulp can replace part of the corn or soybeans, or simply the daily food, this flour has certain properties that contribute to the nutrition of animals, such as fiber, which is very important for the feeding of cattle, since which guarantees the absorption of proteins and other nutrients that corn and soybean contain. In addition, it has been proven that the taste is accepted by animals, especially cattle. Orange pulp is an excellent nutritional supplement in cattle, since it is highly energetic, due to the large amount of carbohydrates; it also stimulates the formation of probiotic bacteria that help improve the health of animals, preventing the growth of food pathogens (Cuevas, 2012).

The need to find alternative methods to antibiotics to reduce the presence of pathogenic bacteria in cattle has led a team from the *Agricultural Research Service* to test the effectiveness of citrus bark and pulp to achieve this goal. They have shown that citrus pulp and bark, specifically orange pulp, helps reduce the presence of *Escherichia coli* and *Salmonella* in the intestine of ruminants. Several previous studies had already shown that citrus fruits provide cattle with an adequate amount of fiber and vitamins, and essential oils have a natural antibiotic effect.

The data obtained have demonstrated the feasibility of using orange pulp as a food source to stimulate the intestinal antimicrobial activity of cattle. Likewise, it has been proven that the consumption of bark and orange pulp is compatible with current production practices in cattle, which eats them without acceptance problems. One of the main problems of the pulp and the orange rind is the transport, since the humidity is very high and that makes the task difficult; however, pelletization avoids this setback. In one of the field experiments carried out with sheep, it was shown that feeding based on orange pulp pellets for eight days, divided by 10 the amount of intestinal *Salmonella* in these animals (Ventura, 2011).

In an investigation, orange flour was incorporated into diets for sheep, to obtain better quality meat and with less fat concentration, it was reported that animals that were fed the diet containing orange flour slightly increased weight and presented less fat; in addition, the consistency and flavor of the meat was superior (Neria, 2010). The fresh orange residue can be used as a useful alternative in feeding the lambs in confinement during the fattening stage, up to 30 % instead of the sorghum grain; this represents a 48 % decrease in feed costs per kg of lamb (Villanueva *et al*., 2013).

The replacement of the final cane honey with citrus silage at levels of 0, 12, 25 and 40% with respect to the dry matter of the final pig diet, did not change the weight gain, observing similar growth curves in all treatments; while the conversion of dry matter decreased ($p < 0.001$) from the 25% inclusion of orange pulp silage, replacing the final honey. The conversion of digestible energy was similar between treatments, although a tendency was observed that they were higher in the first two substitution levels, with respect to the control and the higher level of silage inclusion. The thickness of the dorsal fat decreased ($p < 0.001$) as the final honey was replaced by the orange pulp silage.

Significant correlations were obtained between gain and conversion with the digestive use of dry matter, energy and nitrogen. In general, an increase in the correlation coefficients was observed when the silage of oranges is part of the diet, replacing the final honey, and better correlations of the digestibility of nutrients were obtained with the conversion with respect to the average daily gain. Total energy digestibility was the best predictor of behavioral traits (Dominguez, 1995).

Supplementation with fresh orange waste at levels of 300, 450 and 600 g animal/day, to sheep of different genotypes (Blackbelly, Katahdin and Pelibuey), did not modify (p> 0.05) birth weight, weaning weight and gain daily pre-southeast (2.50 ± 0.15, 9.25 ± 1.57 and 0.11 ± 0.01 kg, respectively, (Ruiz *et al*., 2019).

Preliminary results

Sun drying of fresh orange waste was carried out in the Academic Unit of Veterinary Medicine and Zootechnics of the Autonomous University of Nayarit. The process consisted of placing the waste of fresh orange on a concrete plate for 14 days and with daily movement of the waste, with a shovel, to allow the material to dry evenly. Subsequently, the dried product was ground in a hammer mill No. 20 (figure 2), provided with a 1 cm diameter sieve, in order to obtain the flour. Sun drying of fresh orange waste presented a yield of 23.9% (table 5).

Table 5. Waste yield of sun dried fresh orange

Pulp of fresh orange (kg)	Sun dried orange pulp (kg)	Yield (%)
137.9	35.4	25.7
151.6	38.8	25.6
92.2	22.6	24.5
217.0	51.0	23.5
86.6	20.5	23.7
105.0	23.4	22.3
76.0	19.4	25.5
150.8	32.8	21.8
90.3	23.0	25.5
81.4	17.1	21.0
	Mean	23.9

CONCLUSION

The byproduct of the toy industry and small businesses selling juice is the waste or pulp of citrus, which is composed of the peel, bagasse, seeds, juice, oils and waste fruits. This by-product can be used as a source of dietary fiber and energy in the animal feed of ruminants and non-ruminants (fresh, fermented, dehydrated, molasses, or cake), bed, dextran and fructose production, and compost; however, much goes to the landfill. When dehydrating citrus pulp in the sun has a yield of 23.9%.

Figure 2. Sun drying process and milling of fresh orange waste

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