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Nutrient Composition of Dandelions and its Potential as Human Food

[1]Abdel E. Ghaly, [2]Nesreen Mahmoud and [1]Deepika Dave

[1]Department of Process Engineering and Applied Science,
Faculty of Engineering, Dalhousie University, Halifax, Nova Scotia, Canada
[2]Department of Agricultural Engineering, Faculty of Agriculture, Cario University, Gizza, Egypt

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ABSTRACT

Two thirds of the world's populations are suffering from protein malnutrition and about 36 million people die every year due to hunger. Expansion of present agriculture practices into marginal land is not expected to solve the problem of increasing the food supply. New methods of feeding the ever increasing world population must be developed. The aim of the study was to evaluate the usefulness of the dandelion leaves as a source of supplemental protein. Protein was extracted from the dandelion leaves by blending them after pH and moisture adjustment, squeezing the resultant pulp through filter press and coagulating the filtrate with acid and heat. The effects of pH, moisture content, pressure and temperature on the extractability and quality of protein were investigated. A mass balance was performed on dry matter and protein contents during the extraction steps. Proximate analysis was performed on the extracted leaf protein and the amino acid profile of the protein curd was determined. The best results of the protein dissolution during the blending step were obtained at pH of 8.25 and moisture content of 96%. Firm protein curd with light green chalky color was obtained at 3.5 pH and 80°C. The protein content of dandelion leaves was 4.70% while the protein content of the curd was 15.93% on wet basis and 55.43% on a dry basis. The best leaf protein could be obtained from the young leaves in good conditions. The results showed that dandelion leaves offer a good source of supplementary protein compared to vegetable and fruits. The amino acid composition of dandelion protein seems to be better than most seed proteins and compares favorably with animal proteins. The protein cake at a pH of 4 had the keeping quality of cheese. Drying the protein cake did not impair the nutritional value but made it hard, dry and gritty. The non extractable protein remained in the fibre and liquor; both have economic values as feed for ruminants and growth medium for microorganisms, respectively.

Keywords: Flirtation, Blending, Dandelions, Extraction, Moisture Content, pH, Protein, Amino Acid, Ash, Coagulation

1. INTRODUCTION

It has been estimated that two thirds of the world's population are not receiving sufficient protein in their diet (Ghaly and Alkoik, 2010a). About 36 million people die every year due to hunger or as a result of hunger and approximately 60% of the 11 million deaths each year among children under the age of 5 are attributed to malnutrition (FAO, 2002; WHO, 2002). Expansion of present agricultural practices into marginal land is not expected to solve the problems of increasing the food supply. New methods of feeding the burgeoning population will have to be developed, particularly methods that will guarantee a renewable protein supply, since in many instances it is the lack of protein and not of calories that is the cause of malnutrition (Ghaly and Alkoik, 2010a; Saunders *et al*., 2011). The development of new sources of protein such as single cell protein (Tannenbaum and Wang, 1975; Ferrianti and Fiechter, 1983), insect protein (Finke, 2002; Ghaly and Alkoik, 2010b), soybean protein (Mendez, 2002; Bhatia and Green, 2008), fish protein concentrate (Shahidi *et al*., 1991; Sikka *et al*., 1979) and leaf protein (Faskin, 1999; Ghaly and Alkoik, 2010a) have made significant contributions toward the alleviation of the protein deficiency. However, there is still an estimated one

billion people suffering from protein deficiency (Ghaly and Alkoik, 2010a).

The process of photosynthesis is the only non-depletable protein source. Of the twenty amino acids from which human proteins are built, eight must be supplied to man from the leaves of green plants (Maciejewiez-Rys and Hanczankovwski, 1990; Tangka, 2003). Surprisingly, only one percent of the world's edible plants are being used for human food. Ninety five percent of plant food comes only from twenty crops and in many countries, only six are actually exploited (Parrish *et al*., 1974; Nordeide *et al*., 1996). Protein from leafy vegetables makes up half of all vegetable proteins in the human diet and contributes as much to the world's total protein as does fish, although it receives much less attention (Faskin, 1999; Tangka, 2003).

There are two factors limiting the nutritional value of plants to monogastric animals: (a) the high amounts of fibre and (b) the indigestibility of the cellulosic cell walls. Normally herbivores assimilate the plant proteins and man consumes the herbivore protein and avoids the cellulose. This detour through the food chain is inefficient as only 2-20% of the plant protein fed to animals is recoverable as animal protein for human nutrition. The yield would be much greater if it was possible to eliminate the middle process by extracting the plant protein from the indigestible fibre and eating it directly. It has been estimated that the extraction of protein from an area of land slightly larger than 20,000 ha could produce enough high grade protein per year to feed a population of one million. An equal amount of protein would be left in the fibre to feed livestocks and thus converted to meat and milk (Vaisey *et al*., 1975; Tangka, 2003). The leaf protein is of high quality and adult male would receive about the same amount of balanced protein from equal amounts of leaf protein, meat or milk.

Dandelion, *Taraxacum vulgaris* (**Fig. 1**) belongs to the botanical family *Compositae* which is the characterized by the bearing of many small flowers in a disc (Stewart-Wade *et al*., 2002). Dandelion was brought to North America as a garden plant by settlers (Solbrig, 1971; Tilford, 1997; Heatherley, 1998). The young leaves were used in salads and as medicine while the flowers were used as a dye in dandelion wine. The dandelion is a long-lived perennial with a widely branched root system that can reach 30 cm in length and 3 cm in width. The root serves as a storage organ and is filled with a milk-like fluid that has a high latex content. It is marked with annual growth rings and is surmounted by a spiral shaped crown formed as a result of very short internode (each new leaf is placed with its base very close to the insertion of the previous leaf). When the root is injured or broken near its upper portion, an undifferentiated tissue (the callus) is formed to plug the wound and produces new buds within few days (Solbrig, 1971; Tilford, 1997; Kershaw *et al*., 2002; Kim and Mendis, 2006). The dandelion is a short day plant (does not bloom where there is more than 12 h of light) and the blooming process is very rapid in spring and fall (Solbrig, 1971; Heatherley, 1998; Welch, 2007). Each plant produces 192-252 seeds, each with its parachute pappus. Dandelion is one of the few apomictic plants that can reproduce asexually and survive practically anywhere (Tilford, 1997; Kershaw *et al*., 2002). Fifteen year old dandelions were found (Solbrig, 1971; Welch, 2007).

The objectives of this project were to: (a) extract protein from dandelion leaves (b) determine optimum extraction condition and (c) determine the nutritional value of protein crude.

(a)

Fig. 1. A rosette-shaped dandelion; (a) Flower; (b) Dandelion plant with flowers and roots

2. MATERIALS AND METHODS

2.1. Collection of Dandelions

About 25 kg of dandelions leaves were gathered from the Citadel and the Common Grounds in Halifax, Nova Scotia between July 15 and September 15, 2008. The leaves were thoroughly mixed, backed in plastics bags and stored at -15°C till needed for the protein extraction process. Twenty samples were selected at random and analyzed for moisture content. The average dry matter content of the leaves was 13.62% ± 1.11% (moisture content = 86.38%).

2.2. Protein Extraction

A detail description of the protein extraction process is illustrated in **Fig. 2.** The moisture and pH were first adjusted before the pulping process. The blended material was then filtered under vacuum to separate the juice from the cake. The remaining juice in the cake was liberated using a press. The juices from the filtration and press steps were coagulated by heating and acidifying. Then, the mixture was filtered to separate the protein from the liquor.

2.2.1. Blending

Leaf protein extractability is influenced by moisture content and pH. Optimum extraction can be achieved at moisture content greater than 95% and pH greater than 7.5. These conditions ensure good flow ability of the leaf slurry and softening of the cell wall. In this study, the pH was adjusted by adding of 0.1N NaOH. Five moisture contents (95, 96, 97, 98 and 99 %) were tested. Fifty grams of leaves were placed in a blender (Model V004-43100C, Villa Ware Mfg. Co., Ohio, USA) and 35 cm of 0.1N NaOH was added to bring the pH to 8. The water was then added to bring the moisture content to the desired level. Each sample was blended for 30 sec on "chop" and then for four one-minute periods on blend. Between each blending period, the sides of the glass cylinder of the blender were clean with a spatula, scraping the chopped dandelion leaves down towards the blades.

2.2.2. Filtration

Filtration was carried out on the blended samples to separate the librated leaf juice from the pulp. A Bunchner 17 J funnel (Cat. No. 22086769, Fisher Scientific, Ontario, Canada) with Whatman filter papers (#41, Cat. No. 1441150, Sigma-Aldrich, Ontario, Canada) were used with a 500 mL vacuum flask (Cat. No. 10-181E, Fisher Scientific, Ontario, Canada). The vacuum (3000 psi or 20684.27 kPa) was applied using a vacuum pump (RV5, Edwards vacuum pump, Linde Canada Ltd., Ontario, Canada). The blended leave material was poured into the funnel and the amount of juice passing through the filter was measured every 2 min for the first 20 min and then every 10 min for the next 40 min. Two trials were carried out for each moisture content studied: one immediately after blending and the other after 15 min blending.

2.2.3. Pressing

The filter cake was pressed using a specimen mount hydraulic press (20-1410-115 SimpliMet® 2 Hydraulic Specimen Mounting Press, Buehler Ltd., Illinois, USA) to liberate the remaining juice in the filter cake. Two layers of filter paper (#41 Cat. No. 1441150, Sigma-Aldrich, Ontario, Canada) were used over the strained plate and a pressure of 3000 psi (20684.27 kPa) was applied for 15 min followed by a pressure of 6000 psi (41368.54 kPa) or 5 min.

2.2.4. Coagulation

The aim of coagulation was to separate the protein from the filtered juice while maintaining good consistency and a firm curd. The juices from the blending and pressing steps were combined. Fourteen samples of filtrate (40 mL each) were acidified to pHs of 8.5-2.0 (in 0.5 increments) with 1N HCL and heated to 80°C. The coagulated protein was separated from the liquor by filtration using the Buchner filtration system.

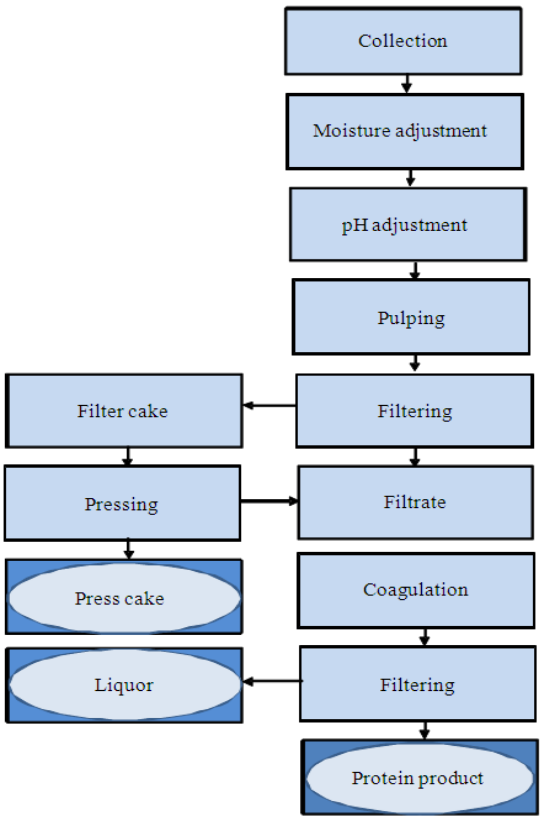

Fig. 2. The extraction process

The temperatures at which the first cured and first liquor appeared were recorded. The quality and the colour of the cured at 80ºC were also recorded.

2.3. Experimental Analyses

2.3.1. Moisture Content

The oven dry method described in APHA (1990) was followed. The samples were first weighted using a Mettler scientific balance (AE 2005, Mettler Instruments, AG, Greifensee, Zurich, Switzerland). They were then placed in a convection oven (Isotemp oven, Model No. 655F, Fisher Scientific, Montreal, Quebec) for 24 h at 105°C. The dried samples were then removed from the oven, left to cool in a dessicator and weighed. The moisture content was calculated as follows:

$$MC = \frac{M_1 - M_2}{M_1} \times 100 \quad (1)$$

Where:
MC = The moisture content (%)
M_1 = The initial weight of the wet sample (g)
M_2 = The weight of the dried sample (g)

2.3.2. Ash Content

The ash content was determined gravimetrically on the dried samples according to the procedure described in APHA (1990). The dried samples were placed in a muffle furnace (Isotemp muffle furnace, Model No. 186A, Fisher Scientific, Montreal, Quebec) for 30 min at 550°C. They were removed from the muffle furnace, left to cool in a dessicator and then weighed using a Mettler scientific balance (AE 2005, Mettler Instruments, AG, Greifensee, Zurich, Switzerland). The ash content was calculated as follows:

$$AC = \frac{M_3}{M_2} \times 100 \quad (2)$$

Where:
AC = The ash content (%)
M_3 = The weight of the material remaining after burning the dry sample (g)

2.3.3. Proximate Analysis

The dandelions tissue analysis (moisture content, protein, fat, carbohydrate and ash) were performed at Maxxam Analysis Inc, Mississauga, Ontario. The analysis was also performed on the dry matter of dandelions.

2.3.4. Fat Content

The fat content was determined using the ether extraction technique according to the procedure described in the Official Method of the Association of Official Analytical Chemists (AOAC, International, 2005). Hot ether was percolated through a porous receptacle filled with ground dandelions leaves for 24 h. The fat was released from the dry matter and collected in a flask at the bottom of the apparatus. The receptacle was removed, dried in a vacuum oven (Isotemp oven, Model No. 655F, Fisher Scientific, Montreal, Quebec) for 24 h at 105°C and then reweighed. The change in weight corresponded to the fat content of the original sample. The fat percentage was computed from the following equation:

$$FC = \frac{W_f}{M_s} \times 100 \quad (3)$$

Where:
FC = The fat content (%)
W_f = The weight of fat extracted (g)
W_s = The weight of the dried sample (g)

2.3.5. Protein Content

The total protein was determined using the Tecator Kjeltec Auto Analyzer (Model-1026, Fisher Scientific, Montreal, Quebec). The ground dandelions leaves were transferred to the macro 250 mL digestion tubes. One "Kjeltab" (containing 3.5 g K_2SO_4 and 0.0035 g Se) and 3.0 mL of distilled water were added to the samples in the digestion tubes. The samples were digested at 420°C for 30 min in a digestion block heater (Tecator Digester System, 20 Model-1016, Fisher Scientific, Montreal, Quebec). The digestion tubes were removed and allowed to cool for 10 min. Then, 30 mL of distilled water was added to each of the digestion tubes. The digestion tubes were transferred to the Auto Analyzer. The constants A and B for the equipment were set at 0.00 and 1.862, respectively. The titrant acid and the predetermined blank sample were set at 0.2127 M and 0.01, respectively. Distillation, titration and calculation were performed automatically. Similar procedures were used to determine the protein contents of the filter cake, press cake, protein curd and filtrates. The protein percentage was computed from the following equation:

$$PC = \frac{\text{Displayed result}}{W_s} \quad (4)$$

Where:

PC = The protein content (%)

W_s = The weight of the sample of live dandelions leaves (g)

2.3.6. Amino Acids

The amino acids (Alanine, arginine, cysteine, glutamic, glycine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, serine, threonine, trytophan, tyrosine and valine) were determined using the HFB-IBA (Heptafluorobutyric isobutyl esters of amino acids) amino acid derivatization kit (Cat. No. 18094, Altech Associates, Inc., Deerfiled, Illinois, USA). The sample was placed in a small reaction vial. An amount of 3 mL of 0.2 M HCl was added to each vial and the solutions were heated to 16500-10, Hach Chemical Co., Loveland, CO) for 30 h. Then, the vials were removed from the heater and dried under stream of dry nitrogen. About 1.25 mL of acetyl chloride (Cat. No. 18094B, Altech Associates Inc. Deerfield, Illinois, USA) was slowly added to 50 mL of isobutanol and the mixture was added to each vial (which contained dry sample). The vials were capped and heated at 110°C for 45 min. The vials were uncapped and heated at 115°C under a stream of nitrogen to remove excess reagent. Then, the vials were removed from the heater and cooled in an ice bath (Precision water bath microprocessor controlled 280 series, Model 284, Cat. No. 1547418, Fisher Scientific, Ottawa, Ontario, Canada) for approximately 5 min. About 3 mL of methylene chloride and 2 mL of HFBA, Cat. No. 18094A, Associates Inc. Deerfield, Illinois, USA) were added to each vial. The vials were then capped and heated at 100°C for 4 h. The vials were removed form the heater and cooled to ambient temperature. The excess reagent was evaporated under a stream of dry nitrogen. The samples were redissolved by adding 2 mL of ethyl acetate and injected into the gas chromatograph (Model-HP5890).

3. RESULTS

3.1. Blending

The results of blending with different moisture content are shown in **Table 1.** The results showed that the 95% moisture pulp was too dry and the chopped leaves were thrown from the blades onto the glass. On the other hand, the 99% moisture pulp was too soupy. The best range of moisture content was 96-98%. The best result was obtained at a moisture content of 96%. However, higher moisture content (98%) cushioned the leaves so that fewer cells were broken during the pulping process.

3.2. Filtration

The juice passed through the filter rapidly at first and then slowed down after a few minutes as shown in **Fig. 3.** The material that was delayed for 15 min after blending did not pass easily through the filter. Only 22 mL of juice were collected after 260 min compared to 114 mL in 60 min for the material that was filtered immediately after blending. This indicated that pulp was aged very quickly.

3.3. Pressing

The purpose of pressing was to liberate the juice remaining in the filter cake. Pressing was tried with one, two and three layers of filter. The results indicated that one layer of filter was not strong enough and three layers backed up the juice causing flow by pass through the o-rings. It was also noticed that a pressure of 3000 psi (20684.27 kPa) was adequate to liberate 16.5 mL of the juice from the filter cake in 10 min. The higher pressure of 6000 psi (41368.54 kPa) liberates another 5 mL of juice from the filter cake in 1 min (**Fig. 4**).

3.4. Coagulation

To ensure the accuracy of the acidity of the coagulation process, it was necessary to determine the buffering capacity of the leaf juice. A sample of 120 mL each of the filtrate was titrated with 1.0 N HCl. The results showed in **Fig. 5** indicated that the pH of the juice was 8.0 and the juice did not have any buffering capacity. The coagulation results are presented in **Table 2**. No coagulation was observed at room temperature under all pH conditions. Only under pH 4.5, a rippling in the dark green juice started at a temperature of 33°C. At52°C, the juice started separating into tea-like liquor from the dark green-brown protein precipitate. The amount of protein coagulated increased with increase in temperature up to 80°C. The protein curd was most firm at a pH of 3.5. Most of the tea-like green liquor passed through the filter in 1 min and no liquid pressed through after 10 min. The curd had a light green chalky appearance with a pH of 3.5. The filtered protein was dried at room temperature.

Table 1. Effect of moisture on the quality of pulp

Moisture content (%)	Added water (mL)	Added NaOH (mL)	Final pH	Observations
86.38	0	35	8.00	Very dry bulb
95	93	35	8.11	Dry bulb and many complete cell walls
96	127	35	8.32	Good cell breakage
97	184	35	8.86	Some cell breakage and some cell lumps
98	297	35	9.07	Poor cell breakage and many intact cell lumps
99	638	35	9.31	Soupy pulp and complete cell wall

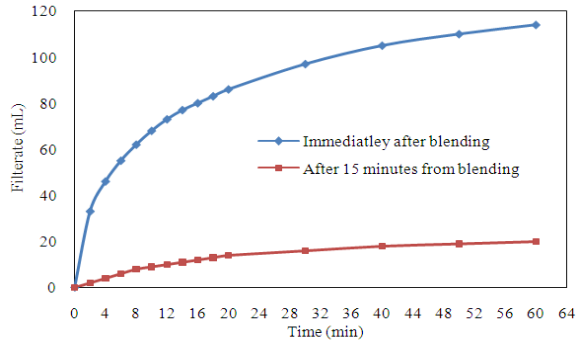

Fig. 3. Liberated juice from filtration immediately after pulping

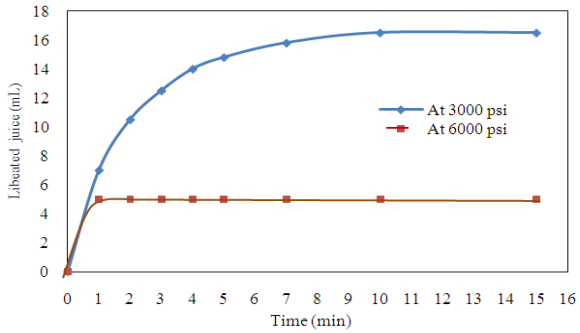

Fig. 4. Librated juice from the pressing

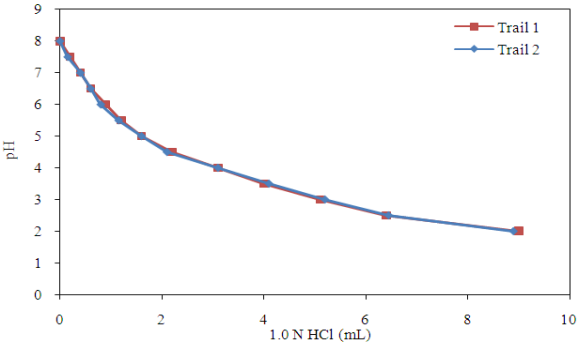

Fig. 5. The buffering capacity of the protein liquor

3.5. Mass Balance

The dry matter and protein contents of the various materials were calculated and a mass balance was performed on the entire protein extraction process as shown in **Table 3**. The final dry matter content of protein curd was 28.74 % with a protein content of 15.93%.

3.6. Protein Quality

The results of proximate analysis of the extracted dandelion leaf protein are shown in **Table 4 and 5**.

Table 2. Effects of pH and Temperature on the formation and quality of curd.

	Temperature			
pH	1st curd appearance (°C)	1st liquor appearance (°C)	Curd quality at 80°C	Curd color
8.0			No curd	
7.5			No curd	
7.0			No curd	
6.5			No curd	
6.0			No curd	
5.5			No curd	
5.0			No curd	
4.5	33	52	Suspension of particles	Dark green gritty
4.0	33	53	Soft curd	Dark green less gritty
3.5	33	54	Firm curd	Medium green chalky
3.0	33	55	Medium curd	Light green very gritty
2.5	33	55	Soft curd	Light green gritty
2.0	33	55	Suspension of particles	

Table 3. Changes in dry matter and protein contents during the extraction process

Material	Total weight (g)	Dry matter (%)	Protein (%)
Mash	177.0	4.00	3.00
Filter cake	60.2	8.03	0.81
Filtrate	113.8	1.74	3.44
Press cake	36.6	16.70	3.87
Press filtrate	21.6	2.03	5.50
Protein curd	26.7	28.74	15.93
Liquor	106.6	1.13	1.31

Table 4. Proximate analysis of dandelions leaves (wet basis)

Parameter	Percent
Moisture	71.26
Fat	4.91
Protein	15.93
Carbohydrate	5.90
Ash	2.00

Table 5. Composition of dandelion leaf protein (dry basis)

Content	Value
True protein	55.43%
Lipid	17.08%
Starch and Fibre	20.53%
Ash	6.96%

The moisture, fat, carbohydrate and mineral contents of the crude protein were 71.26, 4.91, 5.90 and 2.00%, respectively. The protein, fat, starch and fiber and ash contents were calculated on a dry basis as shown in **Table 5.**

4. DISCUSSION

The best leaf protein can be obtained from young leaves that are initially in good condition. A crop that has been cut clean without bruising does not deteriorate quickly if kept under cool conditions. The

protein in the cells was separated from the fibre by first blending (at moisture content of 96% and a pH of 8.25) the mash to dissolve the protein in the cell sap and then filtering the sap.

The protein dissolution depends on the pH and moisture content. The best results were obtained when the moisture content of the leaves was adjusted to 96%. Since the isoelectric point (PI) of most proteins is at a pH between 3.6 and 5 (Widmann *et al*., 2010), the protein solubility was increased by the addition of NaOH. Gout *et al*. (1992) stated that the cell sap is easily liberated at higher pH because the cellulose and other polysaccharides in the cell walls imbibe more water and become softer. As the cell walls swell, they free pectases which further weaken the cell walls. Obara *et al*. (2001) and Kinsella (1970) also stated that alkaline conditions counter act the pH drop that results from the rapture of acidic vacuoles during pulping which would denature the proteins and make it unavailable for extraction. Parrish *et al*. (1974) reported that the basic condition resulted in increasing recoveries of nutritious xanthophylls and carotene as well as better colour stability and harding properties of the final product. Pelegrine and Gasparetto (2005); Pirie (1971) and Jaenicke and Zavodszky (1990) reported that high solubility negatively affect extractability as protein denatured under extreme basic condition (pH of 11-12). Pelegrine and Gasparetto (2005) and Nagy *et al*. (1978) found the optimum range of pH for pulping to be in the range of 8-8.5, within which the solubility of nitrogen was 70-80%.

Pulping must be completed as quickly as possible to avoid sticking of protein to the fibres which render it unexractable. Once the juice is driven from the cells by pulping, it should immediately be separated from the fibre by filtration and pressing. The results showed that filtering the juice after 15 min produced 22 mL of filtrate compared to 115 mL when flirtation was carried out immediately after blending. Callis (1995) stated that given enough time, the protein would stick to the fibres and the leaf proteolytic enzymes would degrade the protein. The importance of rapidity was also stressed by several authors (Cheftel *et al*., 1992; Balny and Masson, 1993; Hayakawa *et al*., 1994). The results showed that the juice liberated at the higher pressure contained more protein than the juice liberated at a lower pressure.

The coagulation of the protein in the juices obtained by filtration and pressing should also be performed very quickly to minimize the action of proteolytic enzymes in the leaves in order to maintain higher protein digestability and preserve the limiting amino acids lysine and methionine. Chloroplast fragments and other organelles began to coagulate when the temperature of the juice reached 50°C. The curd was denser and easily filtered when the juice was rapidly heated. The heat precipitated protein should be crumbled and suspended in water (10 times its weight) with the pH adjusted to 3.5 before filtration. This acid washing process improves the curd texture, removes some of non protein and non lipid constituents, thereby increases nitrogen and carotene contents and washes away some of the alkaloids and other toxic compounds. The protein cake contained 4.91% fatty acids, most of which were linolenic, palmitic and linoleic. The lipids found in protein contained xanthophylls and carotene both of which contain β–carotenes, the precursor of vitamin A.

The dark green brown color of the protein cake resulted from the conversion of chlorophylls to pheophytins. The protein cake at a pH of 4 has the keeping quality of cheese. Drying the protein cake at room temperature did not impair its nutritional quality but made it hard, dry, dark and gritty and difficult to use. The best results was obtained when the moisture content of the protein cake was maintained at 30-40%, wrapped in polyethylene film and stored at -10°C.

Table 6 shows the protein contents of various food groups. The protein content (4.70%) of dandelions is much higher than those of vegetable and fruits, lower than those of seeds and comparable to those of leaves except that of alfalfa. The protein content of the curd was 15.93% on wet basis (**Table 4**) and 55.43% on dry basis (**Table 5**).

Table 6. Average protein content of various plants

Plant	Protein (%)
Seeds (USDA, 2005)	
Peanut	17.30
Sunflower	22.78
Bean	1.82
Wheat (durum)	13.68
Cowpea	23.85
Vegetables (USDA, 2005)	
Artichoke	3.27
Cocksfoot	2.70
Tomato	0.91
Cucumber	0.65
Sweet potato	2.57
Potato	2.50
Fruits (USDA, 2005)	
Apple	0.26
Apricot	1.40
Pear	0.50
Orange	0.81
Strawberry	0.58
Blueberry	0.74
Leaves (Ghaly and Alkoaik, 2010a)	
Alfalfa	16.50
Cabbage	4.47
Tobacco	4.35
Dandelions (Present study)	4.70

Amino acids are critical to life and have a many functions in metabolism. They are the building blocks of proteins, linked together in varying sequences to from a vast variety (several hundred thousands) of proteins (Chaing *et al*., 2007). There are 20 amino acids useful to humans, some of which are essential (**Table 7**) as they cannot be synthesized by the organism and must be supplied in the diet. Eight amino acids are essentials: isoleucine, lysine, methionine, phenylalanine, threonine, tryptophan, valine and lucine (Young, 1994). Cysteine (sulphur containing amino acid), tyrosine (aromatic amino acid), histidine and arginine are required by infants and growing children (Imura and Okada, 1998; WHO, 2007). The amino acids arginine, cyteine, glycine, glutamine, histidine, proline, serine and trrosine are considered conditionally essential, meaning that they are not normally required in the diet but must be supplied exogenously to specific populatipons that do not synthesize them (Furst and Stehle, 2004). Food stuff that lack essential amino acids are poor sources of protein as the body tends to deaminate the amino acids obtained, converting them into fats and carbohydrates (McGilvery, 1979).

Therefore, a balance of essential amino acids is necessary for a high degree of net protein utilization (defined as the mass ratio of amino acids converted protein: amino acids supplied). The recommended daily amounts of amino acids are shown in **Table 8**. Although protein is costly to produce, it is the greatest limitation to growth and good health (Young, 1994). The most disastrous consequences occur in children where protein malnutrition manifests itself in forms of two notorious diseases: Marasmus and Kwashiorkor. These disease cause loss of muscle mass, fatigue, irritability, swelling, edema, decreased immunity, pot belly, light colored thin hair, skin depigmentation, dermatitis, enlarged liver and loss of teeth (Ghaly and Alkoik, 2010a). The amino acid composition of various protein concentration prepared by acid preparation is shown in **Table 9**. Dandelion protein seems to be better than most seed proteins and compares favourably with animal proteins. It is similar to alfalfa protein which has been shown to be a good supplement (better than skim milk powder) to low protein diets for children. Good results were also obtained with pigs, rates and chicken (Rau *et al*., 1972; Vaisey *et al*., 1975).

Table 7. Useful amino acids (Reeds, 2000; Furst and Stehle, 2004)

Essential amino acids	Nonessential amino acids
Isoleucine	Alanine
Arginine	Aspartate
Lysine	Cysteine
Methionine	Glutamate
Phenylalanine	Glutamine
Threonine	Glycine
Tyrosine	Proline
Tryptophan	Serine
Histidine	Asparagine
Valine	Selenocysteine
Lucine	

Table 8. Recommended daily amount of amino acids (WHO, 2007)

Essential amino acids	mg/kg body weight
Isoleucine	20
Lysine	39
Methionine	11
Cysteine	4
Phenylalanine	15
Tyrosine	10
Threonine	15
Tryptophan	4
Valine	15

- The recommended daily intake for infants (less than 1 year old) can be as high as 150 times the adult recommended daily amount but for children under 3 years is 10 times higher than the adults recommended daily amount

Table 9: Essential amino acid composition of various protein sources (Lima *et al*., 1965)

Protein source	Amino Acid*							
	Lysine	Phenylalanine Tyrosine	Methionine	Threonine	Isoleucine	Lucine	Valine	
Animal								
Meat	8.1	4.9	3.3	4.6	7.7	6.3	5.8	1.3
Poultry	8.0	5.0	3.3	4.5	7.8	6.4	5.7	1.3
Egg	7.2	6.3	4.1	4.3	4.1	9.2	4.0	1.5
Seed								
Soybean meal	6.4	4.8	0.6	3.7	3.5	6.1	5.0	1.2
Cotton seed meal	4.9	5.4	1.5	3.7	3.5	6.1	5.0	6.1
Wheat gluten	0.8	6.4	1.5	4.1	3.7	9.2	4.2	0.7
Maize endosperm	3.6	4.5	2.1	3.7	10.5	3.8	5.7	0.5
Leaf								
Alfalfa	6.3	6.0	2.1	5.2	9.8	5.3	6.3	1.6
Dandelion	6.3	6.0	3.2	5.1	9.7	6.1	6.2	1.4

*Weight of amino acids in 100 g protein

The by products of extraction are fibre and liquor. The fibre has long been recognized as an excellent animal fodder. It is more concentrated than the original material and is, therefore, easy to handle. However, the fibre has less nitrogen content than the original material and has less lignification since the plants used for leaf protein extraction are harvested at young age. Any toxic substances that would be in the original plants are washed away during extraction. The liquor can be used as a growth medium for microorganisms as it has a dry matter content of 1.13% and the nitrogen and carbohydrate contents of the dry matter are 0.48 and 4%, respectively. The most important saccharides in the liquor are fructose and glucose.

5. CONCLUSION

The present study showed that dandelion leaves offer a good source of supplementary protein compared to other sources such as vegetable and fruits. The best leaf protein can be obtained from leaves that are initially in good conditions. Clean cutting of leaves without bruising will not deteriorate its quality when kept under cool conditions. The best results of the protein dissolution were obtained at pH of 8.25 and moisture content of 96% during the blending step of the extraction process. Immediate filtration after blending produced 5.2 times more juice compared to filtering after 15 min. Quick filtration and pressing will minimize the action of proteolytic enzymes in the leaves and preserve amino acids. Firm protein curd with light green chalky color.

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