CHAPTER SEVEN

Leaf Concentrate

Leaf concentrate is an extraordinarily nutritious food made by mechanically breaking down certain green leaf crops into three components. This process is sometimes referred to as leaf fractionation. Although very few people have heard of, much less eaten leaf concentrate, it is not a new idea or even a new technology. A French scientist named Hilaire Marin Rouelle (1718–79) published two fairly thorough papers on making curd from green leaves in 1773, over 200 years ago. He mashed several different species of leaves with a marble mortar and pestle, then strained the leaf juice and heated it. A green curd formed and floated to the top before the leaf juice reached its boiling point. Over the next 150 years several scientists probed the nature of proteins found in this leaf curd.

Little was done with this information in the way of practical application until World War II. England, a densely populated island nation dependent on imported food, was at war with Nazi Germany. The German U-boats, armed with torpedoes, were effectively intercepting supply ships heading to England. Fearing that the U-boat blockade could endanger their food supplies, the British began searching for alternative sources of protein. Dr. N. W. Pirie led a team of scientists at Rothamsted Research Station in developing equipment and techniques for extracting protein from the green leaves of alfalfa, wheat, mustard, and several other plants.

After the war ended, food and feed shipments mainly from the US and Canada resumed and the urgency of finding alternative protein sources declined. In 1972 the World Health Organization sharply reduced the recommended amount of daily protein. This further dampened interest in novel protein sources, such as leaf concentrate.

Work did continue, however, on three different fronts. Some of the work, especially that of the British charity Find Your Feet and the American non-profit group Leaf for Life, focused on developing leaf concentrate as a solution to malnutrition in developing countries. Others including the American company Atlantic Richfield and the French cooperative France Lucerne, worked primarily on using leaf fractionation as an alternative means of dehydrating forage crops. Drying crops, such as alfalfa, prevents mold and nutrient loss in the field and makes them easier to transport to commercial animal feeding centers. In these operations the fibrous fraction was the most important economically. The leaf concentrate was more or less a fringe benefit and was sold mainly as a high nutrient additive to chicken and pig feeds.

The third approach, undertaken on a small scale by Michael Cole and his Leafcyle Farm in Devon, England, and more recently by Natural Farmworks in western Canada, sought to develop leaf concentrate for the relatively savvy and affluent health food market. There are numerous similar products, such as algae, spirolina, and dried barley grass juice, already being profitably

Chart 7–1
Nutrients in Selected High Protein Foods

Protein (g)	Iron (mg)	Calcium (mg)	Vitamin A (mg)	Edible Portion 100 g (3.5 oz)
50.8	54.0	3380	3835	Dried alfalfa leaf concentrate
29.0	1.9	22	0	Beef steak
15.0	2.1	66	182	Scrambled Eggs
26.3	0.5	912	257	Dried whole milk
21.4	5.1	113	0	Dry pinto beans

Leaf concentrate composition from E. Bertin (2009). Composition nutritionelle detailée de l'extrait foliaire de luzerne (EFL). Association pour la Promotion des Extraits Foliaires en Nutrition. All others from USDA.

distributed through retail stores, cooperatives and websites to health conscious and/or hypochondriac consumers.

These various approaches to leaf concentrate are not mutually exclusive. Find Your Feet and Leaf for Life projects often involved micro-enterprise elements, whereby local groups sold leaf concentrate enriched products to local health food stores in the countries where the projects were located. Retired executives from France Lucerne established a not-for-profit organization called APEF (Association pour la Promotion des Extaits Foliaires en Nutrition), which has been very active using leaf concentrate in fighting malnutrition in Africa, Nicaragua, Mexico, and elsewhere. They have done outstanding work using leaf concentrate for the nutritional support of people with AIDS in Africa. Both Leafcycle and Natural Farmworks have expressed interest in joining with nutrition intervention projects.

Leaf concentrate has also been called leaf protein, leaf protein concentrate, leaf extract, rubisco protein, and leaf nutrient concentrate. The process of leaf fractionation begins with mechanically separating the leaf juice from the leaf fiber, followed by heating the juice to the boiling point, and then separating the green curd, or leaf concentrate, that forms from the tea colored "whey" on which it floats. The proportions of each of the three leaf fractions formed vary somewhat with the type of green leaf and the type of equipment used. As a rule, 100 kg of leaf crops should yield about:

~ 5 kg of moist leaf concentrate (at 50–60% moisture)
~ 45 kg of fiber (at 50–60% moisture)
~ 50 kg of whey (at 93–98% moisture)

Fractionating leaves to make leaf concentrate simultaneously resolves several of the problems that have prevented green leaves from reaching their potential as a food source. Separating the fiber and the whey greatly enhances both the concentration and the bioavailability of the nutrients in the leaf.

Leaf concentrate is extremely rich in beta-carotene, iron, calcium and protein. In fact it is richer in these essential nutrients than any commonly available foods. Chart 7–1 compares dried leaf concentrate made from alfalfa with several other highly nutritious foods.

In addition to the high levels of nutrients, the nutrient bioavailability is very good compared to other plant-based foods. This is because the fiber from the cell walls has been separated during the process. This combination of high nutrient levels and good bioavailability makes leaf concentrate quite effective in combating malnutrition. Not only are the fiber and water separated in the fractionation, the process also removes hydrocyanic acid, free oxalic acid and nitrates that limit the usefulness of many leaf crops. Because the juice is heated to the boiling point, *E. coli* and most other pathogens are killed.

Leaf concentrate can also minimize the pesticide residues that we consume with many leaf crops. Much of the pesticide applied to lettuce, spinach, and other leaf crops is protecting not the crop so much as the appearance of the crop in the market. Because the leaves are ground to a pulp immediately after harvest, no pesticides need to be used to keep the crop looking pristine.

The astonishing numbers on the composition table are not just for show. Numerous studies have shown that leaf concentrate is able to quickly reverse many of the symptoms of malnutrition, especially of anemia and vitamin A deficiency. These are two of the most common and most damaging of nutritional deficiencies in the world. Daily portions of as little as 6 g (0.2 oz) of dried leaf concentrate can effectively end most anemia and vitamin A deficiency diseases within a few weeks.

MAKING LEAF CONCENTRATE

Leaf concentrate has been and is being made on every imaginable scale, from France Lucerne's factory in Aulnay processing 150 tons of alfalfa an hour, to peasants pounding leaves with wooden sticks. Regardless of the scale and the specifics of the equipment, for the most part the basic process of making leaf concentrate is the same across cultures.

Freshly harvested and washed leaves are ground or pulped, then pressed to separate the leaf juice from the fiber. The green juice is heated quickly to the boiling point. Heat causes a curd to form that floats to the top. The curd is skimmed off and then pressed to remove as much water as possible. This moist leaf curd or leaf concentrate can be eaten directly or dried and ground for later use. If the leaf concentrate has a harsh flavor it is usually the result of not processing the leaves within an hour or two of harvest, burning the curd, or not pressing the whey from the leaf curd thoroughly enough.

The steps in the process are listed on in Chart 7–2 and then described more fully on the pages that follow. The focus here is on domestic and small-scale processing. At the end of this section the benefits and drawbacks of the three scales of operation (domestic, village, and industrial) are summarized. More information on village or intermediate scale processing is available at the Leaf for Life website www.leafforlife.org/PDFS/english/Leafconm.pdf

Industrial scale leaf concentrate is a more specialized field and is largely beyond the scope of this book.

Chart 7–2
Eight Steps to Making Leaf Concentrate

1. Choose a plant known to be a good source for leaf concentrate.
2. Harvest fresh green leaves.
3. Wash the leaves in clean water to remove dust and dirt.
4. Grind the leaves to a pulp.
5. Press as much juice as possible from the pulped leaves.
6. Heat the juice rapidly to the boiling point.
7. Separate the curd that forms from the liquid (whey).
8. Press as much liquid as possible out of this curd.

This pressed curd is leaf concentrate.

MAKING LEAF CONCENTRATE: STEP-BY-STEP

1. Choose a plant known to be a good source for leaf concentrate.

Not all plants have leaves that make good leaf concentrate. Some of the plants that been used successfully are:

Alfalfa or lucerne - *Medicago sativa*
Cowpea - *Vigna unguiculata*
Berseem clover - *Trifolium alexandrium*
Lablab or hyacinth bean - *Lablab purpureus*
Butterfly or Kordofan pea - *Clitoria ternatea*
Collards or kale - *Brassica oleracea*
Mustard - *Brassica juncea*
Swiss chard - *Beta vulgaris var. cicla*
Orach, mountain spinach - *Atriplex hortensis*
Wheat - *Triticum aestivum*
Moringa - *Moringa oleifera*
Lambsquarters - *Chenopodium album*

In any region there are usually two or three plant species that are the most productive or the most economical. Alfalfa *(Medicago sativa)* has been used far more than any other plant. It is considered to be the "Queen of Forage Crops" and is the most widely grown legume in the world. Generally legumes are the best choices because they can fix atmospheric nitrogen. Leguminous plants like beans, peas, clovers, alfalfa, and many tropical trees have nodules on their roots that can turn the nitrogen in the air into ammonia in the soil that can be absorbed by plants. As a result legumes usually have high levels of protein in their leaves.[1]

1 Sometimes different researchers will come to different conclusions about the suitability of the same crop. For instance, I read a very positive report about using Jerusalem artichoke *(Helianthus tuberosus)* leaves for making LC, but in four separate trials I got only harsh-tasting, inedible curd. It is not always easy to determine how the variety and growing conditions of a leaf crop affect the quality and yield of leaf concentrate.

Fewer than 1% of the estimated 350,000 species of flowering plants in the world have been assessed as possible leaf concentrate source plants. A more systematic evaluation of a larger number of possible crops may produce some pleasant surprises. The checklist below gives an idea what to look for in a crop for making leaf concentrate.

Positive Traits for Leaf Concentrate Crops

- known to be edible by humans
- produces large yields of leaves (over 30 metric tons per hectare [27,000 lb per acre] per year)
- moisture content of fresh leaves is above 75% and below 90%
- protein content in fresh leaves is at least 2.5%
- can fix atmospheric nitrogen
- erect, non-twining growth habit for ease of harvest
- resistance to common tropical virus, insect, fungus, and nematode problems

- establishes quickly enough to compete with weeds
- leaves will re-grow after harvest for repeated cuttings
- seed or cuttings for propagation are readily obtainable
- can withstand drought
- can tolerate low fertility, aluminum, and acidity in soil
- can tolerate salinity and high pH
- has multiple purposes (i.e. edible seeds or roots, cover crop, useful for industrial purposes such as medicine, paper, or textile manufacture)

Negative Traits for Leaf Concentrate Crops

- high concentrations of toxins in leaves
- high levels of tannins or phenolic compounds that can bind with proteins and make them difficult to absorb (often indicated when leaf juices coagulate at room temperature)
- leaf juice forms bitter or unpleasant-tasting curd
- leaf juice that doesn't coagulate readily when heated to boiling or forms a very fine soft curd that is difficult to separate from whey
- foamy or mucilaginous leaf juice that is difficult to separate from fiber
- acidic leaf juice
- leaves that are difficult to harvest (How long will it realistically take to harvest enough leaves from this plant for economical production? For a point of reference, an experienced Mexican farm worker in a good stand of alfalfa can cut 200 kg (440 lb) of leaf crop in 15 minutes with a scythe.)

2. Harvest fresh green leaves

Usually the best time to harvest crops for leaf concentrate is in the morning when moisture content is high. The best leaf concentrate yields from plants are achieved by harvesting just before flowering. During flowering nutrients are rapidly moved out of the leaves into reproductive organs. The most economical crops can be harvested more than once. It is important to determine the optimal harvesting schedule and cutting height for regrowth. Obviously harvesting leaves from very tall plants that require ladders, or from plants with a tangled twining nature will be too slow for economical production.

Machetes, scythes, sickle bar mowers and string trimmers have all been used successfully to harvest leaf crops. Avoid rotary lawn mowers as they tend to suck dust and dirt into the chopped leaves that is impossible to remove. If the leaves are chopped during the harvesting process, some leaf juice will be lost before pulping and the leaves will spoil more quickly. This causes a decline in both the yield and the quality of the leaf concentrate but may become unavoidable as the volume of leaves being processed increases beyond a certain point.

If you are working on a very small scale it may be worthwhile to strip the leaves from the stems. There is very little of nutritional value in the stems. Simply removing the stems can nearly double the percentage yield of leaf concentrate. For instance, 100 kg of cowpea crop as cut in the field will have about 55 kg of leaf, 45 kg of stem, and yield about 2 kg or 2% of dry leaf concentrate. If you start with leaves stripped from their stems you should end up with about 3.6% of dry leaf concentrate. You won't get any more leaf concentrate from the area harvested, but stripping leaves from their stems means far less pulping, pressing, and heating per pound of leaf concentrate. However, on all but the smallest scale the amount of labor involved in stripping leaves is prohibitive.

3. Wash the leaves in clean water to remove dust and dirt.

Rinsing the leaves in cool water as soon as possible after harvest will not only remove surface dust and soil but will usually lower the temperature of the leaves and slow their spoilage. Small amounts of leaves can be washed by hand then shaken out to remove excess water before cutting and grinding. For larger quantities of leaves it is advantageous to use a special tank and handle the leaves with clean pitchforks or rakes. In either case remove the leaves from the tank rather than draining the water and then removing the leaves. When the water is drained much of the dirt gets caught in the leaves on its way out. Weed leaves usually don't need to be picked out unless they are known to be poisonous or especially bitter. Rocks on the other hand tend to be hard on grinders.

4. Grind the leaves to a pulp.

Grind the leaves to a pulp as soon as possible after harvesting. When leaves wilt, the pressure inside the cells is reduced and the amount of force required before rupturing the cell wall increases; just as it is harder to burst a half-full water balloon than one that is completely full. (You might want to experiment outside.) The yield of leaf concentrate from most crops will decline 15% in four hours and 50% after nine hours. A big pile of fresh leaves will begin composting within a few hours. You will be able to feel the heat generated by microbial activity in the center of the pile. It does not improve yield or flavor.

There are several ways to grind the leaves to a pulp. The important thing is that they are ground well enough to break open cell walls. I consider grinding to be the most important step in making leaf concentrate. Chopping, no matter how finely, usually won't rupture enough cell walls. For this reason food processors are inadequate, unless used as a pre-chopper for some other type of grinder.

Household blenders work well for small amounts because the agitating liquid sloshes proteins and other nutrients free from the fibrous matrix. They are a good starting place for getting the basic feel of making leaf concentrate. Unfortunately blenders require adding liquid for processing that must later be heated, thus increasing the energy requirements of the operation. If you plan to use a blender, get the most powerful one you can afford. Forget about how many different speeds it has and look at how many watts the motor uses. This is usually posted on the bottom of the blender base. Any blender with less than 600 watts will likely burn out quickly from making leaf concentrate.

Home scale meat grinders sometimes work for pulping leaves. However, leaves that are very wet tend to be messy due to leaf juice pooling inside the grinder, and leaves with long fibrous stems will often clog up ferociously. Using a meat grinder with a hand crank is physically demanding. We have rigged old bicycles to meat grinders with a pulley wheel to lighten the work. This makes a passable but messy exercise bike. There are electric meat grinders available for processing game meat at hunting and outdoor supply stores. You can also try to rig a 1/2 or 3/4 HP electric motor to a hand cranked meat grinder. It needs to be slowed down to no more than 60 rpm with belts and pulleys or a gear motor. I recommend trying the blender first because it is the simplest in terms of machinery.

Even under ideal circumstances, it is impossible to rupture all the cell walls, but some techniques work far better than others. If you can still recognize pieces of leaf after pulping, cell rupture is not adequate. Cell rupture is usually somewhat improved by passing the leaves through the grinder a second time, but the additional energy and labor cost may not be justified.

5. Press as much juice as possible from the pulped leaves.

After the fresh leaves are ground up or pulped, the juice must be separated from the indigestible fiber. This is usually accomplished by pressing the pulp against a fine screen or a strong nylon type filter cloth, such as are used to strain paint. This allows most of the juice to pass through but holds back the pieces of fiber. The pulp should be pressed from a layer no more than 4 cm (1–1/2 in) thick. This gets better results than a thicker layer because when a thicker layer of pulp is pressed, much of the juice from the center of the layer tends to be reabsorbed by the drier pulp at the edge of the layer. Also some of the large protein molecules are unable to pass through a thick layer of densely compacted pulp and so are excluded from the leaf juice. This lowers the yield of leaf concentrate.

Very high pressure is unnecessary and can complicate things by clogging and tearing filters. A pressure of 2 kg per sq cm (30 lb per sq in) applied over a layer of leaf pulp that is initially 2.5 cm (1 in) thick for ten seconds is usually adequate. Pressures as low as one-third of this can be effective if the pulp is repositioned and pressed a second time. After pressing it should not be possible to get more than a drop or two of liquid from the fiber when it is squeezed in your fist.

As any physics student or loan shark can tell you, there are many possible ways to apply pressure. Levers are simple and work reasonably well for quantities of leaves less than a few hundred kilograms. We have used a 3 m (10 ft) long, 10 cm (4 in) diameter steel pipe to apply pressure to a plate about 60 cm (24 in) on a side. This plate presses down on a wire mesh (sometimes called hardware cloth) tray with a wooden frame that holds the pulped leaves in a nylon cloth. A stout wooden board could also be the lever. A car jack can be used to apply pressure with a similar type of plate. The seals fail quickly on cheap hydraulic jacks if they are used repeatedly to press juice from pulped leaves. Screw type or scissors type jacks hold up better but are tiring to use.

Centrifuges of various types, including the spin cycle of automatic washing machines, have also been used to separate the leaf juice from the pulp. This is usually more of an exciting mess than a practical solution. On a domestic scale an extremely simple press made from the legs of blue jeans from secondhand stores work well. Other material, such as muslin, will work fine but use fabric strong enough to hold up to repeated and vigorous wringing. You can add to the pressure being applied by using a broomstick to help twist the cloth. It is a variation on the old fashioned wringing post that was used to wring water from clothes before they were hung to dry.

After you have pressed the pulp, you should not be able to squeeze any more juice out with your bare hand. The residual fiber should be a lighter shade of green than the original leaves. You can eke out a little more concentrate by re-wetting the fiber and pressing it a second time. As with a second pulping, a second pressing takes additional time and energy and may not be worth the effort unless you have a very limited supply of green leaves or the initial pressing was not done well.

The leaf juice should be strained through a screen or cloth before heating, to remove particles of fiber. This can be done with an open weave cloth (such as the nylon used in pressing the pulped leaves or a thin cotton t-shirt type fabric) inside a sieve or colander.

6. Heat the juice rapidly to the boiling point.

Leaf concentrate is separated from leaf juice by coagulating the proteins and lipids into a curd. Many other nutrients are pulled into this curd. The most effective way to coagulate the leaf juice is to heat it rapidly. While most of the leaf curd or concentrate will form by the time the leaf juice reaches 65° C (147° F), it is very important to continue heating the juice to the boiling point. This serves several purposes, including:

- Pasteurization of the leaf concentrate to kill most of the harmful microorganisms that may have been on the leaves from the soil or from handling.
- Neutralization of enzymes in leaf juice. Enzymes, called lipoxidases, can cause off-flavors; more rapid deterioration of the concentrate; and the formation of pheophorbides, substances that cause sensitivity to light and allergic reactions in some people.
- Formation of a firmer curd that is much easier to separate from the leaf juice than the soft curd that forms in juice that is not heated to boiling.

Heating should be as rapid as possible. Heating slowly will cause a reduction in yield. It can result in curd that is soft and fine textured. This type of curd is undesirable because it seals up filter cloths that are used to separate the curd from the remaining liquid or whey. Slow heating also results in greater fuel costs, as more heat is lost to the air. The heat should be turned off as soon as the boiling point is reached. Holding the juice at the boiling point for more than a few seconds will cause some loss of vitamins as well as greater fuel costs, without providing any benefits.

The simplest way to heat leaf juice, and the method used most often in small projects, is to put it in a large shallow pan over a hot flame. This is a familiar process for many women around the world who bring liquids to a boil over fire several times a week (i.e. for beans or breakfast porridges). The pot should have a top to conserve heat. Heavy gauge stainless steel is the best material for the cooking pots in terms of cleaning and not contaminating the juice. Aluminum pots are generally much cheaper and more readily available than stainless steel and acceptable for this use. Unless they are very scratched they won't leach an appreciable amount of aluminum. Light gauge or thin-bottomed pots of any material should be avoided because there will be more problems with curd burning on the bottom of the pot. Burning of curd can be greatly reduced by gently scraping across the bottom of the cook pot a few times just before the juice reaches the boiling point.

Steam injection is used on large scale leaf concentrate operations because it generally uses less energy to coagulate the leaf juice. Steam will instantly coagulate leaf juice, making a good quality curd with no risk of burning it. To make steam work on a domestic or village level might require adapting some type of steamer used for cleaning clothes, carpet, or cars. On a very small scale a household pressure cooker might be adapted. It is important that the safety concerns of using very hot water under pressure are adequately addressed.

Another idea is to trickle leaf juice into a pot of water that is held near the boiling point.

A curd forms almost immediately and floats to the surface. The advantage of this system over heating in a pot is that it is continuous and that the curd never burns because it doesn't stay in contact with the bottom of the pan. The drawbacks are that it is more difficult to arrange and coordinate and that the juice is not heated as conclusively to the boiling point, thus pasteurization may not be as thorough.

There are a number of ways to obtain curd from leaf juice without using heat. These include centrifuging, ultra-filtration, fermentation, and acidification. At this point none of these techniques seems to be superior to heat except under specific laboratory circumstances. For home or small scale leaf concentrate production heat is clearly the preferred way to coagulate leaf juice.

7. Separate the curd that forms by filtering through an open weave cloth.

After the leaf juice reaches the boiling point it should be removed from the heat and allowed to stand for a few minutes to cool. Leaving the curd in the hot liquid a few minutes assures better pasteurization with no further fuel costs. Letting the liquid cool a bit before separating the curd also reduces the chance of being scalded from hot liquid. The cook pot should never be filled completely, especially if it is going to be moved while there is hot liquid in it.

If the quantity of juice heated at one time is fairly small, it can be handled by pouring the entire contents of the cook pot through a filter cloth of nylon type material. This cloth can be supported by a wooden frame that has 62 mm (1/4 in) woven wire mesh (hardware cloth) fixed to its bottom. This can be the same wooden frame that is used in pressing the juice from the pulped leaves. This frame can be set on a washtub so that the whey will pass through the cloth and be collected in the tub below. The relatively large surface area and open weave of the cloth will allow the whey to drain freely from the curd.

If the pot is too large to lift comfortably, skim the curd off with a slotted spoon or a strainer. The skimmed curd can be put into a colander lined with a nylon cloth to drain the whey.

8. Press as much liquid as possible out of the curd.

The curd is then placed in a stronger, more tightly woven cloth, like muslin, denim, or cotton-polyester twill, and pressed to remove as much whey as possible. An easy way to press the whey from the curd is to spread it in a layer not more than 2.5 cm (1 in) deep on the muslin or twill cloth and press it gradually with a lever. This process is nearly the same as the pressing of the juice from the fiber, except the pressure must be applied a bit more gradually and held for a longer time. As with pressing the juice, reorienting, or repositioning the curd in the filter cloth for a second press usually results in better pressing. When using a lever, a weight, such as a five-gallon bucket of water, can be used to apply steady pressure. This type of steady pressure on the lever for several minutes is ideal for pressing the whey from the curd.

On the domestic scale we have gotten good results with a wringing pole approach (see step 5 above). In fact this technique is the only simple press that consistently results in leaf concentrate that is below 60% moisture.

After being pressed the curd should be crumbly and contain about 60% moisture. Even with phenomenally strong hands you cannot get either enough juice from the pulped leaves or enough whey from the curd by simple hand squeezing.

What remains in the cloth is leaf concentrate.

PRESERVING LEAF CONCENTRATE

Fresh leaf concentrate is quite perishable. Like tofu or fresh cheese, it will last one or two days at room temperature or about a week in a refrigerator. Because of this, it is often advantageous to preserve leaf concentrate for later use. Preserving it enables you to make a larger quantity less frequently. This greatly reduces the amount of set up and clean up work per unit of leaf concentrate produced. More importantly, preserving leaf concentrate allows you to have it year round, even where leaf crops are plentiful only at certain times of the year.

The simplest way to preserve leaf concentrate is by drying it to below 10% moisture. Other methods are to mix it with enough sugar, salt, or acid, or combination of them to inhibit microbial growth. The leaf concentrate should be preserved as soon as possible after it cools because bacteria will quickly begin to multiply on the surface. The rich nutrient content that makes leaf concentrate so beneficial for humans also promotes rapid growth of many microorganisms. Leaf concentrate, whether fresh or preserved, should be stored in a container that is as airtight as possible, and it should always be stored in a location that is cool, dry, and out of direct sunlight.

Drying leaf concentrate

Drying leaf concentrate is very similar to drying fresh green leaves. Almost all of the information on drying leaf vegetables in Chapter 8 applies to drying leaf concentrate as well. There are numerous commercial food dryers for sale, and designs for building your own solar and electric powered dryers are available and listed in the appendix. However, the solar leaf dryers described in the next section of this book are inexpensive, easy to build and work well with no fuel costs.

As with leaves, leaf concentrate should be dried as quickly as possible. Preferably the concentrate should be completely dried on the same day that the curd is made. Like fresh leaves it needs to be protected from the ultraviolet rays of direct sunlight, as well as from blowing dust, insects, and rodents.

Steps for Drying Leaf Concentrate

1. Start with well pressed curd (c. 60% moisture)
2. Granulate the curd by rubbing it through a screen or hardware cloth to get small, uniformly sized particles. This will increase the ratio of surface area to weight and ensure faster and more thorough drying.
3. Heat the granulated curd: 50° C (120° F) is ideal, 60°C (140°F) is the maximum.
4. Expose the granulated curd to moving air to remove the moisture that evaporates from the surface of the concentrate. The solar dryers are designed to provide enough air movement and most electric dryers have small fans.
5. Dry to below 10% moisture. If you're not sure that the concentrate is thoroughly dry, you can finish drying it in an oven set to the lowest possible temperature for a few minutes then turned off before the leaf concentrate is put in the oven.
6. Grind as finely as possible. If the friction from grinding makes the dried curd too hot to touch comfortably, grind it more slowly. Finely ground, dried leaf concentrate has a less gritty feel in the mouth than more coarsely ground concentrate. It also provides more surface area for digestive enzymes to work and thus the nutrients are better utilized. The information on grinders and grinding in chapter 8 generally applies to grinding leaf concentrate also, although the higher protein content makes the dried concentrate harder to grind than dried leaves.
7. Store in thick, well-sealed plastic bags or other opaque containers with as much air removed as possible. Keep in a cool dark place. Use within one year

Preserving fresh leaf concentrate with sugar or salt

Sugar and salt can preserve food because their high osmotic pressure kills bacteria by drawing moisture through the bacterial cell walls. As a rule of thumb in food preservation, for each kilogram of water in a food, you need 3 kg of sugar or 200 g of salt. This means that 1 kg of fresh leaf concentrate at 60% moisture contains 600 g of water and needs to be mixed with 1,800 g of sugar or 120 g of salt.

For each kilogram (2.2 lb) of fresh leaf concentrate, mix with:

- 2 kg (4.4 lb) sugar + 1 liter (4-1/4 cups) lemon juice
- Blend leaf curd and juice together at high speed, then add sugar to make lemonade syrup that will keep for six months or more in a refrigerator. The lemon juice compensates for some of the sugar because it lowers the pH of the concentrate which also inhibits microbial growth.

OR

- 2 kg (4.4 lb) sugar + 1 liter (4-1/4 cups) water or fruit juice + 40 g (1.4 ounces) salt
- Salt helps preserve concentrate and reduces settling when syrup is mixed with water.

OR

- 2 kg (4.4 lb) sugar + 1 liter (4-1/4 cups) water or fruit juice + 40 g (1.4 ounces) salt
- + 1,600 mg vitamin C
- Vitamin C, or ascorbic acid, lowers pH and is an antioxidant that helps preserve leaf concentrate. It also makes the concentrate's iron easier for the body to utilize. This formula provides about 40 mg vitamin C per 10 g serving of dried concentrate.

OR

- 2 kg (4.4 lb) sugar
- This makes a paste that can be added to many sweet foods and drinks.

OR

- 200 g salt
- This can be mixed and stored in an airtight plastic bag, or layered and stored in brine, like sauerkraut (fermented cabbage leaves). The salt needs to be washed off before it is eaten. Sauerkraut and other fermented leaf foods are generally preserved by a combination of lactic acids lowering the pH and the osmotic pressure of salt. (See Chapter 9)

Storing leaf concentrate is not an exact science. Its shelf life will depend on the methods used and the percentage of moisture in the curd, as well as the condition in which it is stored. No matter how long it has been stored, it is a good idea to smell it and examine it closely before using it. If it smells like rotted vegetation or has any visible signs of mold on it, do not use it.

USING LEAF CONCENTRATE

Fresh leaf concentrate is a dark-green-colored food with a texture that ranges from crumbly to pasty. It can be used in a wide assortment of dishes, from simply tossing a spoonful into a blender with some fruit juice or yogurt, to elaborate casseroles. It can be added to homemade pasta, used in sauces, such as pesto or green Mexican salsa, or baked into cookies. The flavor it imparts depends on the type of leaf that was used in making the concentrate. Most leaf concentrate has a fairly strong, spinach-like flavor. The texture is easily adaptable to a variety of recipes. Leaf curd preserved with sugar or salt is very similar to fresh leaf curd in how it can be used. Obviously sugar-preserved curd is easier to incorporate into sweet recipes, and salt-preserved concentrate does better with savory dishes.

For the most part dried concentrate can be used in the same ways as fresh. It is about 2–1/2 times more concentrated so you don't need to use as much to get the same nutritional benefit. Dried leaf concentrate will settle in watery drinks or soups but will stay held in suspension in thicker drinks or stews. For example, dried leaf concentrate powder might sink in apple cider or orange juice, but not in drinks with blended banana or other whole fruit. Because dried curd from some types of leaves has stronger flavor than curd from others, try to match the dried curd to the recipe. Use mild flavored leaf concentrate in cookies or pudding for kids but you might use stronger flavored concentrate in a sauce with chili and garlic.

We have adapted dozens of recipes from all over the world to include leaf concentrate. You will find many of the simplest ones in the recipe section of this book. Be creative. Try adapting some of your favorite

Chart 7–3
Selected Nutrients in Alfalfa Leaf Concentrate

	Protein g	Iron mg	Calcium mg	Vitamin A mcg RAE	Vitamin E mg
DRI* for 4–8 year old child	19.0	10.0	800.0	400.0	7.0
10 g (0.35 oz) dried alfalfa leaf concentrate	5.1	5.4	338.0	384.0	9.9
Percentage of DRI for 4–8 year old child	27%	54%	42%	96%	141%

* Dietary Reference Intake (DRI):Recommended Daily Intakes for Individuals, US National Academy of Sciences, 2004

A note on dietary guidelines. A set of guidelines called Recommended Dietary Allowances (RDA) was developed during World War II by the US National Academy of Sciences. The standards were to be used for nutrition recommendations for the armed forces, civilians, and overseas populations who might need food relief. The allowances were meant to provide superior nutrition for civilians and military personnel, so they included a "margin of safety." The RDA list was revised every five to ten years to incorporate new information. In 1997 RDA became one part of a broader set of dietary guidelines called the Dietary Reference Intake (DRI) used by both the United States and Canada. The DRI guidelines are meant to represent the nutrient requirements of some 97% of the population. The amounts recommended are higher than most people actually need. There are minor differences in recommendations from the nutritional authorities in different countries. It is not an exact science, and political and bureaucratic imperatives add confusion to the mix.

Alfalfa *(Medicago sativa)*

recipes to include a nutritional boost from leaf concentrate.

Because leaf concentrate is such a nutritionally dense food, you don't need to eat very much of it. Ten grams (about 2 teaspoonfuls) of dried leaf concentrate, or 25 g (about 4 teaspoonfuls) of fresh concentrate, is a typical daily portion for both children and adults. This will provide a significant contribution to the recommended allowance of several important nutrients, notably protein, iron, calcium, vitamin A and vitamin E. A trial in Bolivia was able to reverse serious anemia in children very quickly using just 6 g (0.2 oz) of dry leaf concentrate a day.[2]

Chart 7–3 on page 72 gives an indication of what nutrients small amounts of leaf concentrate can provide. It is worth remembering that these nutrients will have much greater value in our bodies than the same quantity of the nutrients in other plant-based foods because of the higher bioavailability.

Economic issues are often the biggest factors in determining how much leaf concentrate to use. As with any food, when the cost of leaf concentrate goes up it tends to be used in smaller portions in order to save money. Viewed as a commodity, leaf concentrate is an expensive food. It will always be more expensive than rice or beans and often more expensive than eggs or cheese. However, when considered as part of a preventative health care system, leaf concentrate can be very inexpensive nutritional insurance. The French organization APEF claims that 20 euros or about 30 US dollars will pay for a year's supply of 10 g (0.35 oz) portions of leaf concentrate for one person. The value of reversing or preventing anemia and vitamin A deficiency in a woman or child is many times that.

One of the major cost advantages of using dried leaf concentrate is that it is so dense nutritionally that very little is needed. A single 44 kg (100 lb) sack could supply 12 people with a 10 g portion of leaf concentrate for every day of the year. This means that shipping and storage costs are low.

Leaf concentrate by-products

When any fresh green leaf crop is fractionated, three products are produced; the leaf concentrate, the residual fiber and the residual liquid (whey). Neither the residual fiber nor the whey can be consumed by humans in large quantities. The fiber is too fibrous and the whey may contain nitrates, potassium, and other salts at levels higher than is beneficial for human consumption. However, both of these by-products are economically important to successful leaf concentrate operation. While they are not directly useful as human food, they can contribute indirectly to improved food security and food quality as animal feed and garden fertilizers.

At a domestic level the fiber is fed to rabbits, guinea pigs, goats, sheep, horses, or cows; and the whey is used as a garden fertilizer. At a village scale the fiber is almost always used for ruminant animal feed and the whey can be either used as a soil amendment or added to the fiber to make silage for cattle. At an industrial scale the whey is evaporated down to a syrupy consistency and added to the fiber, which is then dried and made into pellets for sale to animal feeding operations.

It is important to realize that when figured on a dry-weight basis, the fiber left over from leaf concentrate processing has approximately the same feeding value to animals as unprocessed fresh leaf crop. Although much of the protein has been removed in the leaf concentrate, the residual fiber still retains adequate protein for good cattle feed. Grinding the leaves up well in the process gives the fiber far more surface area than the original leaf crop, which enables the cow's digestive system to extract nutrients more effectively. Because fresh alfalfa and other leaf crops are usually around 20% dry matter, while the residual fiber is around 30% dry matter; the fiber has about 1–1/2 times the feeding value, per kilogram, as the leaves that it was made from.

Considerable experimentation has been done by many different groups to develop

2 The Effect of a Leaf Concentrate Supplement on Haemoglobin Levels in Malnourished Bolivian Children: A Pilot Study, by Lowe, C.A. 1991. (www.leafforlife.org/PAGES/BOLIVIR.HTM)

Chart 7–4
Leaf Concentrate Production at Varying Scales

Domestic Scale	
Fresh leaf crop per hour	8 kg
Fresh leaf crop per day (240 days per year, one hour half per day)	4 kg
Dried leaf concentrate per day (3% yield stripped leaves)	120 g
10 g servings per day	12
Residual fiber per day	2 kg
Land required (140 tons/hectare yield)	70–100 sq m
Estimated # of dairy cows & heifers that can be fed	less than 1
Potential milk production	100 liters/year
Village Scale	
Fresh leaf crop per hour	200 kg
Fresh leaf crop per day (240 days/year, 5 hours/day)	1,000 kg
Dried leaf concentrate per day (2% yield)	20 kg
10 g servings per day	2,000
Residual fiber per day	500 kg
Land required (70 tons/hectare yield)	3.4 hectares
Estimated # of dairy cows & heifers	11
Potential milk production	21,000 liters/year
Semi-Industrial Scale	
Fresh leaf crop per hour	2,000 kg
Fresh leaf crop per day (240 days/year, 7 hours/day)	14,000 kg
Dried leaf concentrate per day (2% yield)	280 kg
10 g servings per day	28,000
Residual fiber per day	7,000 kg
Land required (70 tons/hectare yield)	48 hectares
Estimated # of dairy cows & heifers	150
Potential milk production	500,000 liters/year

alternative uses of the leaf concentrate by-products. For example they can be used to make biogas, which in turn can be used to heat the leaf juice. Oyster mushrooms have been grown on a substrate of residual fiber. The fiber can be used as a soil enriching organic mulch for intensive vegetable gardening. Efforts to make paper and fiber board from the fiber fraction of the leaf crop have been more interesting than economically viable. Ultimately, feeding the remaining fiber to ruminant animals seems like a good match because of the high nutritional and economic value of meat and milk.

Leaf fractionation at three scales of operations

Leaf concentrate has been made at every scale, from the domestic 2 kg of fresh leaves a day, to the industrial with 150 tons of leaf an hour. There are advantages and drawbacks at each end of the spectrum.

It is relatively easy to scale up a bit from the domestic level. Five or six families could get together and rotate responsibility for making curd. On the next level a school, church orphanage or social club could make leaf concentrate for up to 100 children, with a modest investment in equipment. This would require processing about 40 kg (88 lb) of fresh leaf a day.

A small family business or cooperative micro-enterprise could process 100 kg (220 lb) of leaf crop a day and make marketable products from the leaf concentrate.

There has been some limited success selling leaf-concentrate-enriched pasta, lemonade syrup, snacks, and sweets.

Beyond 10–20 kg (22–44 lb) a day of leaf crop, it becomes necessary to use some sort of external power for pulping leaves. As the scale increases the business model generally takes over. Once a business model is in effect, it generally requires paying cash for crop, labor, and building space. At this point the enterprise comes into direct competition with other food and nutrition businesses, larger entities that typically have very low overhead and established distribution networks. "Small is Beautiful" meets "Get Big or Get Out." This is, not coincidentally, the point where most of the possibilities for local control drain out of leaf concentrate operations.

To be economically feasible leaf concentrate operations have three basic requirements, whether the scale of operation be domestic, village, or industrial.

- An inexpensive source of appropriate green leaves for much of the year.
- A relatively energy-efficient process.
- An economical use for all three leaf fractionation products.

Chart 7–4 on page 74 summarizes the basic math of the three scales of leaf concentration production. Below is a brief look at some of the advantages and drawbacks of each scale.

Domestic or Household Scale Leaf Concentrate Production

Pros

At the smallest scale, leaf concentrate can be made by a single family, an extended family or a group of friends or neighbors. A significant advantage of domestic scale production is that all of the product can be used fresh. This greatly simplifies packaging and storage, as well as eliminating the steps involved in preserving and marketing the curd. The flexibility to use a greater range of plants, different growing systems, and various work schedules offers the small producer some of the economic benefit that he can't realize in volume discounts and mechanized processing. The initial investment in equipment is small and no special buildings are required. A family goat or rabbits and a family vegetable garden can usually make good use of the relatively small amounts of residual fiber and whey produced, without any special arrangements.

Domestic production can make valuable use of labor that is often available outside the money economy. High rates of unemployment and underemployment increase the appeal of obtaining some food without needing cash. Home production can also be more easily integrated with other activities. A mother making leaf concentrate can simultaneously keep an eye on her children or cook beans with the same fire that heats the leaf juice. Working at home and not needing to arrange childcare and transportation to a job can be a major bonus for low-income families. As the high cost and environmental impact of shipping food thousands of miles to our tables becomes more evident, homemade food begins to look more reasonable. Another big plus for domestic scale production is that the health of the family making the leaf concentrate is often visibly improved.

Cons

The biggest drawback to making leaf concentrate at home is the significant amount of work required per unit of production. Domestic scale electrical equipment is somewhat ill-adapted at best and prone to mechanical failure. Manually operated equipment is more reliable but labor intensive. In addition the time and effort involved in setting up and cleaning up afterwards is about the same if making a small amount or a large amount of concentrate. When output is low, labor costs are high, compared to larger scale operations.

Training of workers can be more complicated at the domestic scale. Per person output of domestically produced leaf concentrate is a small fraction of per person output at larger scale operations using more powerful processing equipment. To achieve the same level of production of concentrate at the domestic level, many more people need to be trained. Quality control is also difficult to maintain when there are many small-scale producers. When there is no

DISTRIBUTED NETWORKS AND SMALL SCALE LEAF CONCENTRATE

Leaf concentrate on the household scale has often been written off, sometimes by me, as economically unrealistic. Too much work for too little food. Making leaf concentrate at home makes no more sense within an industrialized food economy than baking bread, growing a vegetable garden, or raising a few chickens in the yard. Yet all these activities persist not just from nostalgia, but because of their own economic logic. In fact, when the world's financial markets briefly faltered in the autumn of 2008, the sales of how-to books on backyard vegetable gardens and chickens increased by 50%. It doesn't take much insecurity to make you wish you had a back-up plan for getting food.

If domestic scale leaf concentrate is to play a real role in our food security it won't be from a smattering of resolute neo-Luddites making leaf curd in isolation. It will require a distributed network of interested people sharing the most up-to-date information available. This network could collectively provide training, test new leaf-growing techniques and equipment, share recipes, etc. People would be less likely to get discouraged and many beginners' mistakes could be avoided.

Most of us have come to see increasing economic and social consolidation as inevitable if not always desirable. Since the beginning of the industrial revolution, centralization has appeared to be the only game in town. Farms get larger, the number of firms competing in most sectors has gotten smaller, mega-cities swell as villages disappear. However, all is not well with centralization.

In the fall of 2008 it was deemed necessary for a massive government bailout of failing US financial and insurance companies to be enacted. Leaders feared that these corporations were "too big to fail" without pulling the entire national and even international economy down with them. Bernie Sanders, one of the few independent legislators, reasonably suggested that a company that was "too big to fail" was just too big.

The tragedy of airplanes smashing into the World Trade Center towers on September 9, 2001, jolted the world and left us feeling more vulnerable. Dozens of protective and defensive measures were quickly put into place to minimize the possibility of something like this happening again. There seemed to be, however, little attention focused on the inherent vulnerabilities of highly centralized endeavors. Having those thousands of office workers work in dozens or hundreds of smaller but linked buildings might be another route to greater security.

The phenomenal success of the Internet is largely due to the inherent power of a dynamic organization model called the distributed network. Although the Internet is continually subject to malicious attacks, it is able to resist them because it has no single head that can be severed. Important information is stored in multiple places and quickly shared through billions of links, any one of which can be broken without bringing down the system.

There are many successful models that could be drawn from in creating a distributed network for small scale leaf concentrate. For example, MoringaNews was established in 2002 to offer people working with the moringa plant reliable information and a platform to exchange knowledge, products and services. Within eight years it grew to over 2,100 members in over 100 different countries, and is now a real force in making moringa an effective tool in fighting malnutrition.

Seed Savers Exchange, Inc. is a non-profit membership organization that permanently maintains more than 24,000 endangered vegetable varieties. Its membership functions as a distributed network of people swapping heirloom vegetable seeds and information.

Another example of the power of distributed, as opposed to centralized or decentralized, networks is Wikipedia. Begun in 2001 as a free online reference encyclopedia, by 2010 Wikipedia had over 65 million visitors looking up information each month. There are more than 91,000 active contributors working on more than 15,000,000 articles in more than 270 languages. The encyclopedia is written collaboratively by largely anonymous Internet volunteers who work without pay.

As the speed of communication increases and the cost of information decreases, the advantages of distributed networks are becoming clear to more people every day. For small scale leaf concentrate to reach its potential a supportive web will be required. It could link people from all over the world working on different aspects of leaf concentrate.

boss or cash incentive, production can become overly casual and excuses for not doing the work too easy to find.

Village or Small Business Scale

Pros

Leaf concentrate production can be taken on by a village or neighborhood social group, a church group, or a small, perhaps family-owned or cooperative business. More leaf concentrate is produced than can be consumed by the families making it. The social support for this scale of production can be important, especially if the community feels the health of their children will benefit. This can help with securing the initial capital required for processing equipment. The prospect of flexible part-time local employment can be an important motivator. When leaf concentrate is made at this level, and enriched products are sold locally, there can be a multiplier effect. Local farmers might find a new market for their crops, and money spent on the leaf concentrate products circulates close to home. This stands in stark contrast to the prevailing economic pattern of money spent on processed food quickly leaving communities.

The small number of workers involved can be well-trained in the new techniques, greatly improving quality control over domestic production. Because the workers at this scale use powered equipment they are able to produce much more leaf concentrate per hour of work than people working on the domestic scale.

Cons

The promise of village or small business scale leaf concentrate has so far been difficult to realize in practice. Effective processing equipment for this scale is not available off the shelf, and so needs to be custom built. This is not only initially more expensive but it is harder to find replacement parts and mechanics capable of maintaining custom built machinery. The financial return is often not sufficient to justify constructing or redesigning a building to meet the specific needs of efficient production. This is especially true where good leaf crop is not available at reasonable cost for a large part of the year.

At this scale it becomes necessary to market both the leaf concentrate and the fiber. Although the fiber is a valuable feed, it is an unknown and may be seen as a waste product that local farmers are unwilling to pay a fair price for. While the whey is a valuable resource for fertilizing soil, it is almost impossible to sell. If farmland for recycling the whey is not nearby, it may become a waste disposal problem. Marketing leaf concentrate or concentrate-enriched products can require a complex and sometimes expensive registration process with local health

Bolivian stone grinder

LEAF CONCENTRATE AND HIV/AIDS

Two-thirds of the estimated 33 million people suffering from AIDS live in sub-Saharan Africa, the poorest region in the world with the highest rates of malnutrition. The rate of infection there is six and a half times higher than the world's average infection rate.[1] Because HIV/AIDS weakens or kills adults in the prime of their working life, it has a crushing impact on the region's already shaky economy, engendering more childhood malnutrition and preventable illness.

People infected with HIV have greatly increased nutritional requirements, as they must fight the infection while trying to rebuild muscle and regain lost weight. People with the disease remain in better health for much longer if they can gain access to a balanced diet with plenty of protein. It is a doubly difficult task. Typically income, and with it the ability to purchase food, declines with the infection, while expenses for medical care go up. Not only does the disease make far more demands on the body, it often reduces a person's ability to digest foods and absorb nutrients. Mouth sores, nausea, diarrhea, damage to the intestinal linings and apathy can make eating arduous. All of these difficulties call for a diet especially rich in nutrients with high bioavailability.

Where meat, milk, and eggs are inaccessible, and even beans may be too expensive, how can these people get the nutrient-dense, easily digested food they need? Leaf concentrate may be part of the solution. With high levels of easily digested protein, vitamins and minerals, leaf concentrate is a nearly ideal food for people with increased nutritional needs, such as malnourished children and people with AIDS.

The French NGO APEF (Association pour la Promotion des Extraits Foliaires en Nutrition) has supplied leaf concentrate made from alfalfa to groups working with AIDS patients in Burundi and Cameroon. The early results of their studies have been extremely encouraging. Almost all the patients gained weight, became less anemic, and had fewer problems with diarrhea, respiratory infections and skin lesions. This was true whether they were receiving anti-retroviral medicine or not.[2]

1 AIDS epidemic update. December 2009 Joint United Nations Program on HIV/AIDS. http://data.unaids.org/pub/FactSheet/2009/20091124_FS_global_en.pdf

2 http://www.nutrition-luzerne.org/anglais/pdf/Cameroon%20compte%20rendu%20et%20situation%20180%20days%2020-8-07%20English.pdf While the leaf concentrate is currently being imported from France, given some institutional support, there is no reason why Africa could not produce its own leaf concentrate. This could improve the quality of life for millions who are suffering now. Perhaps it could buy time until effective measures to cure the disease and prevent its further spread can be found.

authorities.[3] This may be more justified at the industrial scale, while it is not necessary at the domestic level.

Industrial Scale

Pros

By far the biggest advantage of industrial scale production, and it can hardly be overemphasized, is the low cost per unit of leaf concentrate produced. Whatever benefit leaf concentrate can bring to malnourished people may be determined by its per kilogram production cost. Malnourished people usually don't have enough money to buy adequate food. The low unit production costs of industrial leaf concentrate can make it much more readily available to the people who most need it, rather than just to wealthier, health conscious people. This is especially important given rising food prices and the shrinking number of subsidized social food programs.

At the industrial scale, the large initial investment in specialized equipment and operating space can be justified by the high output. This scale can sustain a well-conceived marketing effort for the large amounts of residual fiber and whey, which are combined, dried, and pelletized for confined or concentrated animal feeding operations (CAFOs). Because industrial operations buy such large volume of leaf

3 3 The 2009 decision by the European Food Safety Authority (EFSA) approving alfalfa leaf concentrate for general human consumption might make registration easier.

crop they usually pay much less per ton than smaller processors for their raw material.

Quality control is good at this scale, and the consistent dried leaf concentrate can be registered, incorporated into products, packaged, and sold more easily than the more variable products from smaller scale operations. The reliable quality, good shelf life and extraordinary nutritional density make industrially produced leaf concentrate an excellent candidate for use in Ready to Use Therapeutic Foods (RUTFs)[4]. There is always a need for RUTFs to nourish the people in refugee camps, war zones, droughts, and natural disasters.

Cons

Industrial scale leaf concentrate originated as a by-product of dehydrating alfalfa. The leaf concentrate is normally sold to feed chickens and pigs (monogastric animals), while the fiber and whey are combined and dried for cattle feed. The entire forage dehydration industry is in serious trouble because of the rising cost of the energy used to dry the crop. The large quantities of leaf crop required greatly limits the number of potential sites where new industrial operations could be located. Not many areas

4 Note: RUTFs are high energy, fortified ready to eat food recommended primarily for the treatment of severely malnourished children. They should be soft, palatable, and easy for children to eat without any preparation. They must have a long shelf-life and resist micro-organism contamination.

Alfalfa leaf concentrate processing plant, Aulnay, France

Wolfberry *(Lycium barbarum)*

could meet the demand for a steady supply of 150 tons of good leaf crop per hour that a factory such as France-Lucerne of Aulnay requires. The logistics are daunting. If the crop is chopped into small pieces in the field, leaf juice is lost and yield declines. If it is not chopped it is harder to handle and transport. Delay for any reason quickly leads to enormous piles of leaf crops beginning to compost, damaging both the quality and the yield.

The fixed costs of having an industrial scale processing center and skilled well-paid workers with benefits are so high that economically feasibility may require keeping the machinery running two shifts for as long a season as possible. In the tropics (where the malnutrition is) this usually means having irrigated leaf crops. Unfortunately the cost of irrigation is rising, and it is more likely to be reserved for higher value crops like tomatoes or melons.

In order to attract the investment capital that is needed, a profitable market for human grade leaf concentrate will need to be developed. This will require a quantum shift of focus from the blunt economics of animal feeds to the complexities of marketing a relatively unknown food for human consumption.

Domestic scale leaf concentrate in practice

Since very few readers are likely to begin industrial or even village scale leaf concentrate production it may be useful to take a more detailed look at the domestic or household scale.

A person with a hand cranked meat grinder or a kitchen blender can make 100 g (3.5 oz) of fresh leaf concentrate from 2 kilograms (4.4 lb) of fresh leaves in less than an hour. This can provide the five members of their family with a 20 g portion (equivalent to 8 g dry) each. The nutritional value of the concentrate has been described elsewhere. The economic value to the family might include a reduction in the number of sick days and lower healthcare costs.

To have fresh leaf concentrate daily over the course of an eight-month growing season this family would need to obtain only a total of 500 kg (1,100 lb) of fresh leaves. Although the yields of leaf crops vary greatly with climate, soil, variety, planting density and cultivation techniques, there are many crops that can produce over 25 tons of fresh leaf per hectare, and several that can produce more than double that. This means the entire leaf crop needed for the year could be raised on less than 200 sq m (about 2,000 sq ft) of land. Put in perspective, this is about 1/6th the size of the average American house lot, or about 1/25th the size of a football field.

Leguminous leaf crops are especially well suited for leaf concentrate on the smallest of scales as well as at greater volume. Legumes lend themselves to intercropping. For example cowpeas (*Vigna unguiculata*) or lablab beans (*Lablab purpureus*) can be grown in between rows of maize, sorghum, millet, cassava, yams, bananas, or fruit trees. Rather than hacking down weeds that compete with these crops, the subsistence farmer could raise multi-purpose leguminous crops that fix atmospheric nitrogen and reduce the need for costly fertilizer. The intercrop is mutually beneficial to both crops. Just 600 sq m (6,000 sq ft) of maize, cassava, or bananas intercropped with cowpeas could reasonably produce enough cowpea foliage for this family's leaf concentrate, without competing with the other crops. The tender leaves of the cowpea can be eaten as a potherb, as they are in much of Africa and southern Asia. The immature pods and mature seeds are valuable foods, and the foliage and stems make excellent feed for ruminants. If about 1/30th of the area planted in cowpeas is allowed to produce seed for replanting, the farmer can avoid the ongoing cost of buying seed.

In addition to intercropping, fast-growing crops for leaf concentrate can be grown before or after a grain crop. Cowpeas, lablabs, bell beans, field peas and butterfly peas are excellent because they fix enough nitrogen to benefit the crop that follows, or to replace nitrogen used by the preceding grain crop. In this way the entire growing season can be economically utilized. Some non-legume leaf crops such as amaranth are enormously productive. Under intensive cultivation leaf amaranth can be ready to harvest in 30 days and produce up to 170 metric tons per hectare (70 tons an acre) of fresh leaf in a year. Alfalfa and perennial clovers do well as an undercrop in fruit or nut orchards. The multiple uses for many of the best leaf concentrate crops provide the small grower or part-time farmer with much appreciated flexibility.

As the amount of leaf crop required diminishes, the number of possible sources increases. Children could gather 2 kg of pigweed (*Amaranthus retroflexus*) or lambsquarters (*Chenopodium album*) while weeding a neighbor's corn field. A section of a garden or field could be set aside for growing leaf crop. It is worth noting that gardens can produce much higher leaf yields per square meter than field crops because they are more intensively cared for. Those without adequate land for growing crops can often find vendors in the market selling alfalfa or other good forage for horses and other animals.

There are many potential improvements that could make small scale leaf concentrate a more attractive option for fighting malnutrition, especially micronutrient deficiencies. Ironically increasing energy costs could help leaf concentrate. Lowering energy inputs is essential if we are to develop a sustainable food system. Leaf fractionation can reduce the need for synthetic nitrogen by utilizing more biological nitrogen fixation and at the same time reduce the feeding of grain to animals. These are perhaps the two biggest energy drains in the current global food system. Small scale leaf concentrate production could be effectively integrated into both the agricultural and the nutritional sides of a more sustainable food system.

The excellent nutritional value of leaf concentrate can be seen as a function of adding energy to leaf crops. In a way it is very similar to feeding the leaf crops to cows. A cow will eat alfalfa and convert it to a smaller amount of nutritionally valuable meat or milk, and a larger amount of lower value manure and urine. In the leaf concentrate process we convert alfalfa into a relatively small amount of nutritionally valuable leaf concentrate, and a larger amount of lower value fiber and whey. The energy required to separate the fiber from the leaves moves leaf concentrate towards the top of trophic pyramid, increasing its quality while decreasing its quantity. As with the production of meat or milk, the additional energy required to move the leaves up the trophic pyramid results in a higher-cost product.

Leaf concentrate is an extraordinary food but it is not a miracle food. It will very likely assume a much larger role in the diet of people throughout the world as kinks in machinery and process are ironed out. There are some situations where it is already the most appropriate food choice and there are other situations where circumstances may delay it from becoming a viable option.