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9. ABSTRACT

A review of the history of the Buffalo gourd, its morphology, genetical, and botanical characteristics, its potential as a food crop and in general, the "State of the Art" regarding this feral species as of 1974. The feral xerophytic Buffalo gourd, Cucurbita foetidissima, has evolved in the semi-arid regions of western North America and is well adapted to desert environments. It has abundant yields of seeds rich in edible oil and protein and abundant carbohydrate reserves in the form of starch in the large storage roots. This wild perennial has the potential of being a crop adapted to arid to semi-arid lands, producing additional food critically needed to feed the world population.

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THE BUFFALO GOURD (Cucurbita foetidissima) HBK

A Potential Crop for the Production of Protein, Oil, and Starch on Arid Lands

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Office of Agriculture
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AGENCY FOR INTERNATIONAL DEVELOPMENT
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THE BUFFALO GOURD (Cucurbita foetidissima) HBK

A Potential Crop for the Production of Protein, Oil, and Starch on Arid Lands

by

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Office of Agriculture
TECHNICAL ASSISTANCE BUREAU
AGENCY FOR INTERNATIONAL DEVELOPMENT

FOREWORD

The Office of Agriculture, Technical Assistance Bureau of the U. S. Agency for International Development (TA/AGR/AID) is issuing a series of technical bulletins on subjects of primary importance to the developing countries. This issue should be of especial interest to those in the arid and semiarid parts of the world. As a potential new crop, the gourd described could provide an additional source of quality protein and oil from the seed and is a possible source of starch from the root. Furthermore, it may be grown on land on which few crops will grow.

Additional basic research as well as data on production methods are needed and it is hoped that this publication will stimulate further studies of the Buffalo gourd in countries where it might be adapted. The information contained in this bulletin is essentially a summary of a seminar sponsored by the University of Arizona, Tucson, October 10, 1974. The major participating agencies in addition to the University of Arizona were the Ford Foundation and AID.

Extra copies may be obtained from TA/AGR, through the USAID Missions, or through the Regional Offices overseas. Requests for more detailed information should be directed to this office or to the authors.

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Introduction

There is a world food shortage, particularly in the vast areas of arid and semiarid agricultural lands on which crop production is uncertain depending on local precipitation. The feral xerophytic Buffalo gourd, Cucurbita foetidissima, has evolved in the semiarid regions of western North America and is well adapted to desert environments. It has abundant yields of seeds rich in edible oil and protein and abundant carbohydrate reserves in the form of starch in the large storage roots. Thus, this wild perennial has the potential of being a crop adapted to arid to semiarid lands, producing additional food critically needed to feed the world population.

This publication reviews the history of the Buffalo gourd, its morphology, genetical and botanical characteristics, its potential as a food crop and in general, the "State of the Art" regarding this feral species as of 1974.

Taxonomy

Cucurbita foetidissima HBK was first described in 1817. Its natural habitat is western United States and Mexico as far south as Guanajuato (Bailey 1943).

This plant was later mistakenly named Cucumis perennis by James (1820) who found it growing from "arid and sandy wastes, along the base of the Rocky Mountains, from the confluence Arkansas, and Boiling Spring Fork, to the sources of the Red River" (Bailey 1943). Asa Gray transferred it in 1852 as Cucurbita perennis, and under this name it remained

until 1881 when Cogniaux brought up the name Cucurbita foetidissima of Humbolt, Bonpland and Kunth, having seen the Bonpland specimen in Paris (Bailey 1943). Just when the common name, Buffalo gourd, was coined is obscure. It apparently first appeared in the literature in the paper by Shahani et al. (1951). The term Buffalo gourd is currently in common usage.

Plant Morphology

Cucurbita foetidissima is perennial by virtue of the exceedingly large fleshy storage root it produces. Dittmer & Talley (1964) described a single root which weighed 72 kg for the central tap root alone. The uppermost lateral, which was dug out for a distance of 305 cm, weighed an additional 9 kg. Dittmer & Talley (1964) further described a C. foetidissima plant:

> Some idea of the prodigious vegetable growth of which C. foetidissima is capable is shown by the number of stems and shoots arising from the large tap root described here. Growing from the broad apex of this root, which had a maximum circumference of 4.7 ft. (143 cm.) were 60 short, vertical, perennial stems which produced a total of 360 annual shoots. These shoots spread out on all sides of the central crown covering an area of 40 ft. (12.2 m) in diameter. The average length of each shoot was 20 ft. (6.1 m) and many of these gave rise to secondary branches. If only the number of primary shoots were considered, with their average length of 20 ft. (6.1 m), this plant would have a vine with a linear dimension of 7,200 ft. (220 m), all developed in a five month growing season. Counts were made of the number of leaves on 100 shoots, and the total number for this plant was calculated to be 15,720. Although this number seems high, we found that the leaves

arise individually on the stems with a spacing of 4-6 inches (10-15 cm) between the nodes. If we calculate the number of leaves based on a growth of 7,200 linear ft., we again come close to the 15,000 figure.

Leaves of C. foetidissima are typically entire and heart shaped with a 10-13 cm base and 20-25 cm length. The photosynthetic capability of these plants must be tremendous.

The flowers are borne singly at the nodes of the vines after a given amount of annual vegetative growth has taken place. Most observed under wild conditions are monoecious with the early flowers being male as well as the most abundant flowers being male. However, Curtis (1974) has isolated a genetic mutant which causes the male flowers to abort when approximately 1 cm long (fully developed male flowers are 10-12 cm long) and to produce more female flowers than the monoecious plants. In 1973 Curtis observed a mean of 272 fruit per plant for the 10 best mutant plants and a mean of 209 fruit per plant for the six highest yielding monoecious plants. The plants were in their third fruiting season and spaced 3m x 3m.

Cross pollination between flowers, even though they may be on the same plant, is necessary for fruit and seed development. This is accomplished mainly by the squash and gourd bees, Peponapis and Xenoglossa, throughout its natural range of habitation (Hurd, Linsley & Whitaker 1971). The size of the fruit is known to vary, probably due to seasonal growth fluctuations and competition. Ba-Amer and Bemis (1968) collected open pollinated fruit from a homogeneous population of plants. The mean fruit weight was 119.6 g with a

mean number of seed per fruit of 292. Three years later Costa and Bemis (1972) collected open pollinated fruit from the same plant population which had a mean of 151.8 g per fruit and a mean of 315 seed per fruit. The seeds weigh about 4 g per 100 and the seed coat accounts for about 30% of the seed weight (Hensarling, Jacks & Booth 1973). The remainder of the seed or 70% is the oil and protein rich embryo which constitutes, in addition to its root reserves, that portion of the developed plant to be utilized as an agricultural crop.

Mode of Reproduction

Cucurbita foetidissima is a prolific producer of fruit and seed. As the fruit matures it abscisses from the vine and dries to a very thin fruit wall. At this point, seed produced by wild colonies of plants is extremely susceptible to predators such as rodents, birds and other seed-eating animals. Most observers of this plant share the opinion that its asexual mode of reproduction is probably the major method of dense colony formation of plants in areas of summer rainfall. Every node of the vine has the potential to develop an adventitious root if the moisture content of the soil or sand surface is sufficient and coincides with an appropriate physiological stage of development of a given node. In this manner large homogeneous colonies are developed and, coupled with the perennial nature of the root system, continue to expand in size.

Under domestication, the Buffalo gourd could probably be successfully established either directly from seed, indirectly by transplanting seedlings, or by transplanting adventitious roots.

Interspecific Relationships

numerical taxonomy study of Cucurbita relationships (Bemis et al. 1970) has shown that C. foetidissima is not phenotypically similar to any other species or species group that were studied. Bemis & Whitaker (1969) describe four restricted xerophytic species, C. cylindrata Bailey, C. cordata Wats., C. palmata Wats, and C. digitata Gray. Although a fifth species, the wide ranging and variable C. foetidissima HBK, is truly xerophytic, it is only distantly related to the four above mentioned restricted species.

Many attempts have been made to hybridize the Buffalo gourd with other Cucurbita species and the only reported success was using it as a pollen parent with Cucurbita moschata, a domesticated species (Grebenscikov 1956, Bemis & Nelson 1963). In both cases the underdeveloped embryos had to be cultured and the hybrid although vegetatively vigorous was completely sterile. Bemis (1970) successfully produced the amphidiploid of the hybrid and restored female fertility. The diploid hybrid at metaphase I configuration of meiosis contained from three to five loosely associated bivalents and 30 to 34 univalents (n=20). The amphidiploid contained 40 bivalents at metaphase I. However, the

particular C. moschata cultivar used in the initial cross contained a genetic factor which when combined with the C. foetidissima genome resulted in genetic male sterility. Other C. moschata cultivars which do not contain this incompatibility factor have been found and another attempt at producing fertile amphidiploids has been initiated.

Genetic Variation

If, as suggested, the primary node of reproduction is asexual then one would not expect to observe much evidence of genetic variation paricularly within a colony which would essentially represent a clonal line. However, among colonies, especially those separated by great distances, one would expect to find variation. Bailey (1943) states, "This plant is so variable in leafage that one may wonder whether more than a single species is involved."

Curtis (1974) in his nursery in Lebanon where he had a population of 730 plants from a rather limited number of crosses and selfs, all originating from a common seed source, has observed and described seven unique plant types. In 1972 Dr. Curtis had oil and protein analysis made for 50 selected plants. The oil content varied from 25.6 to 42.8 percent and protein from 22.2 to 35.1. It is unknown if these differences are significant, but they are suggestive that genetic differences do exist for oil and protein content and can be selected to improve the crop.

Composition of the Seed

The economic importance of the oil and protein in Buffalo gourd seed is especially vital now during a protein and oil shortage in much of the world. This shortage, especially the protein, is very critical in both human and animal nutrition, and encompasses the world from Central and South America through Africa to the Far East. In order to bring about a balance between population and the agricultural supply, it is necessary to develop new sources of protein- and oil-rich seeds.

Average values for crude protein and crude oil in Buffalo gourd as analyzed by three different laboratories were approximately 32 and 30 percent for the protein and oil, respectively (Table 1). A large variation in individual values occurred when 50 different individual plant sources were analyzed (Curtis 1972). Jacks et al. (1972) calculated the average amounts of oil and protein in decorticated *Cucurbita* seed and found that they contained 35.0 ± 2.4% protein and 49.5 ± 2.3% oil.

Table 1. *Cucurbita foetidissima* Whole Seed Quality Expressed as a Percent of Seed Weight.

Source	Curtis (1946)	Shahani et al. (1951)	Weber (1973)	Weber et al. (1969)
Protein	34.2	31.7	31.3	32.3
Oil	33.9	24.3	31.4	30.4
Fiber	17.4	26.5	25.0	----
Ash	4.8	4.8	----	----

Oil Content

Linoleic acid, which is a polyunsaturated fatty acid, comprises 60 percent of the oil derived from the Buffalo gourd seed. This fatty acid composition indicates that Cucurbita seeds are valuable sources of edible oil. Linoleic acid is the essential fatty acid required by both humans and animals in given daily amounts as specified by species requirements.

The fatty acid contents of several edible oil seeds are compared in Table 2. The Buffalo gourd seed would have to be ranked second to safflower oil because of its linoleic acid content and the ratio of unsaturated to saturated fatty acids. The Buffalo gourd oil has a linoleic acid value of 61 percent while safflower oil has a level of 75 percent. The two oils most commonly used for cooking are corn and cottonseed oil. These two oils have levels of linoleic acid of 54 and 51 percent, respectively. The ratio of unsaturated to saturated fatty acids for corn and cottonseed oil were 3.18 and 3.40, while the Buffalo gourd oil was 4.45.

TABLE 2. FATTY ACIDS OF VARIOUS VEGETABLE OILS

KIND OF OIL	14:0 1/ MYRISTIC	16:0 PALMITIC	18:0 STEARIC	18:1 OLEIC	18:2 LINOLEIC	18:3 LINOLENIC	UNSATURATED 2/ SATURATED
	%	%	%	%	%	%	
BUFFALO GOURD OIL	0.9	9.3	4.2	23.1	61.0	1.5	4.45
CORN OIL	---	13.0	4.0	29.0	54.0	T	3.18
SOYBEAN OIL	T	11.0	4.0	25.0	51.0	9.0	3.40
COTTONSEED OIL	1.0	29.0	4.0	24.0	60.0	T	1.18
OLIVE OIL	T	14.0	2.0	64.0	18.0	2.0	3.00
PEANUT OIL	T	6.0	6.0	61.0	22.0	T	2.00
SAFFLOWER OIL	T	8.0	3.0	13.0	75.0	1.0	6.82

1/ RATIO OF TOTAL CARBON ATOMS TO NUMBER OF CARBON - CARBON DOUBLE BONDS.
2/ THE RATIO OF UNSATURATED TO SATURATED FATTY ASIDS.

The feasability of using Buffalo gourd seed for production of oil and crude protein can be justified by examination of other oil seed sources as listed in Table 3.

Table 3. Analysis of Whole Seed

Type of seed	Crude protein	Crude fat	Crude fiber	Moisture	Ash
Buffalo gourd	31.3	31.4	25.6	4.9	4.8
Soybean 1/	37.9	17.4	5.3	9.1	4.9
Winged bean 2/	38.6	15.5	3.8	7.8	3.6
Cottonseed 1/	23.1	22.9	16.9	7.3	3.5
Sunflower 1/	16.8	25.9	29.0	6.4	3.1
Sesame 1/	22.3	42.9	10.3	8.0	5.6

1/. Atlas of Nutritional Data on United States and Canadian Feeds by the National Academy of Sciences.

2/. From J. D. Watson, Ghana J. of Agrl. Sciences 4 (1):95-111

The processing of cotton, sunflower and sesame seed into usable products is a well established procedure. This has been accomplished although both cottonseed and sunflower seed have a lower initial concentration of crude protein in the whole grain than Buffalo gourd seed. The soybean was initially developed for its oil, but now is a dual purpose seed commodity, with great demands for it as a protein source. The 17.4 percent oil in whole soybean is relatively low. Table 4 lists the composition of various oil seed residues after the extraction of the oil. All of the oil seed byproducts are valuable protein concentrates used in both food and feed.

Table 4. Analysis of Meal

Type of meal	Crude protein	Crude fat	Crude fiber	Moisture	Ash
	(%)	(%)	(%)	(%)	(%)
Buffalo gourd[1/]	50.0	3.0	10.0	7.0	10.1
Soybean	48.5	1.0	3.0	10.0	5.6
Cottonseed	41.4	1.5	12.4	7.5	6.4
Sunflower	46.8	2.9	11.0	7.0	7.7
Sesame	47.0	5.0	6.0	7.0	11.3

1/. Estimated values for Buffalo gourd meal based on whole seed analysis.

Protein content

The whole Buffalo gourd seed contains by weight approximately 31 percent crude protein. This protein level is high than that of other oil seeds with the exception of soybean (Table 3). But when oil and/or fiber of the seed are removed the protein level increases relative to the other crops shown in Table 4, and it is reasonable to assume that the meal of the Buffalo gourd would have a higher protein content than most other oil crops, probably greater than 50 percent.

To assess Cucurbita seeds for food uses, the amino acid composition of the meal, as listed in Table 5, was evaluated (Table 6) according to the chemical score (Mitchell and Block 1946), protein score (FAO/WHO 1973), and essential amino acid index (Oser 1959). The evaluation procedure compared the amino acid patterns of the test protein to that of whole egg protein. In addition, Buffalo gourd seed quality was compare with the resulting meals of soybean, cotton seed, sunflower, and sesame.

Table 5. *Cucurbita foetidissima* Protein Quality Expressed as Percent of Protein.

Amino Acids	Sources of Data			
	Lyman et al. (1956)	Weber et al. (1969)	Hensarling et al. (1973)	Weber (1973)
	(%)	(%)	(%)	(%)
Lysine	3.3	4.0	3.3	4.5
Histidine	1.9	2.1	2.5	2.2
Arginine	14.2	13.0	16.8	13.0
Threonine	2.6	1.5	3.5	2.4
Valine	4.8	4.0	5.0	3.8
Methionine	1.9	1.4	2.5	1.2
Isoleucine	4.4	3.2	4.1	3.3
Leucine	6.6	4.6	7.8	5.4
Tyrosine	---	3.9	3.9	4.0
Phenylalanine	4.6	---	5.9	3.6
Aspartic Acid	---	---	10.9	9.5
Serine	---	---	5.9	4.1
Glutamic Acid	---	---	21.5	17.2
Proline	---	---	4.5	2.7
Glycine	---	---	4.8	8.1
Alanine	---	---	5.0	3.3
Cystine	---	---	0.7	0.9
Tryptophan	1.6	---	0.6	1.0

The quality of the Buffalo gourd as calculated by the methods of chemical and protein score is compared to other oil seeds in Table 6. The protein score ranks Buffalo gourd close to four of the other protein sources but sunflower meal was substantially higher. Both the chemical and protein score methods had the same first limiting amino acid. With the Buffalo gourd, soybean and cottonseed meal, the sulfur amino acids were first limiting, while sunflower and sesame meal had lysine as their first limiting amino acid. The essential amino acid index (EAAI) ranked the protein sources in a different order than either the chemical or protein score. The cottonseed and Buffalo gourd had the lowest values -- 61 and 66, respectively. The EAAI and biological values (B.V.) ranked the proteins in a closer approximation to values obtained with feeding studies.

TABLE 6. PROTEIN QUALITY EVALUATION

PROTEIN SOURCE	CHEMICAL 1/ SCORE	PROTEIN 1/ SCORE	FIRST LIMITING AMINO ACID	ESSENTIAL AMINO ACID INDEX (EAAI)	E/T-RATIO 2/ (g/g)	BIOLOGICAL VALUE (B.V.) 1/
		(%)		(%)		(%)
BUFFALO GOURD	37	50	SULFUR	61	2.18	55
SOYBEAN MEAL	53	58	SULFUR	85	2.58	61
COTTONSEED MEAL	47	54	SULFUR	66	2.15	60
SUNFLOWER MEAL	54	72	LYSINE	71	2.11	68
SESAME MEAL	44	50	LYSINE	78	2.47	73
WHOLE EGG REF.	100	100	---	100	3.22	100

1/ A WHOLE EGG REFERENCE PROTEIN USED.
2/ E/T-RATIO = TOTAL ESSENTIAL AMINO ACIDS TO TOTAL NITROGEN.

Two species of animals were used to test the protein quality of Buffalo gourd seed in separate studies using the parameter of protein efficiency ratio (PER). Comparable results were found between the rat and mouse for PER values of C. foetidissima (Table 7).

Table 7. Effect of Dietary Protein Source in Rat and Mouse Feeding Trials.

Dietary source of protein	Protein Efficiency Ratio (PER) Rat[1/] (10%)	Mouse[2/] (7%)
Casein	3.56	---
Whole egg	---	3.40
Buffalo gourd (without seed coat)	2.36	---
Buffalo gourd whole seed	---	2.79
Buffalo gourd whole seed (Autoclaved)	---	2.24

1/. Jacks et al. 1972.

2/. Weber 1969 and 1972.

The decorticated Buffalo gourd seed when fed to rats had a PER value of 2.36 while the whole seed fed to mice had a PER of 2.79. These rat and mouse PER's indicate that the Buffalo gourd protein is comparable in quality to the other oil seed meals discussed previously.

Buffalo gourd seed fed at 5, 10, and 15 percent levels in a practical chick diet demonstrated the value of the protein by its replacement of soybean meal (Table 8). The Buffalo

gourd replaced 23.5 percent of the dietary protein when fed at the 15 percent level in the diet. The third week body weights and feed conversion data were not significantly different.

Table 8. The Effect of Various Levels of Buffalo Gourd Seed in Chick Diets.

Replacement of soybean meal by Buffalo gourd seed in diet	Buffalo gourd seed as % of total protein	Third week body weight	Feed conversion	Liver GOT activity
	(%)	(g)	(Ratio)	(Sigma)
Control	0	443	1.58	151
Control + 5% Buffalo gourd	7.85	445	1.64	122
Control + 10% Buffalo gourd	15.65	429	1.63	135
Control + 15% Buffalo gourd	23.50	405	1.60	123
		N.S.1/	N.S.1/	N.S.1/

1/. Nonsignificant at the 5% level of probability.

Starch in the Root

Laboratory studies (Berry 1974) of the root of the Buffalo gourd have established that it contains an abundant quantity of starch. Roots of plants in their second year of growth were collected for study. After washing and trimming, they were disintegrated in dilute salt solution by means of a mechanical food blender. Subsequent operations of filtration,

settling, washing and drying provided a homogeneous starch. The starch yield was 50 - 56 percent of the dry weight of the roots.

Confirmation of the identity of the isolated material as starch follows from its intense deep blue color reaction with iodine solution, its hydrolysis with dilute acid to yield only glucose as shown by paper chromatography, its x-ray diffraction pattern typical of starches, and its characteristic granular structure as revealed in photomicrographs. Other physical and chemical properties are under study.

Isolation in the manner described provides a starch which is free of cucurbitacins, the extremely bitter glycosides which are present in the roots, leaves and fruit of this gourd.

The Buffalo gourd is compared with certain other starch sources for moisture and starch content on a freshly harvested basis in Table 9.

Table 9. Moisture and Starch Content of Certain Starch Sources

Source	Starch designation	Moisture	Starch
		(%)	(%)
Solanum tuberosum	Potato	75-78	19
Manihot utilissima	Tapioca	60-75	12-33
Maranta arundinaceae	Arrowroot	65-75	22-28 1/
Cucurbita foetidissima	Gourd root	68-72	15-17

1/. Industrial yield typically 15% due to the dense cell walls surrounding the starch.

Crop Yields

The major site of agronomic research on the Buffalo gourd has been in Tel Amara, Republic of Lebanon, under the direction of Dr. L. C. Curtis (Curtis 1974). Other plantings have been initiated in India, Mexico and Iran with seed and information supplied by Dr. Curtis as well as plantings initiated in Arizona in 1973 and expanded in 1974.

Virtually no information regarding yield data based on established field plantings is available. However, several estimates have been proposed based on single or few plant populations. Curtis and Gomez (1974) have calculated yields ranging from 2,928 to 5,241 kgs/ha depending on the initial plant population and the ratio of male steriles (gynoecious) to monoecious plants.

An economic study at the University of Arizona indicates that a yield of 2,000 kgs/ha would be the break-even point based on U. S. economics.

Until cultural plots of Buffalo gourd plantings are established and yield data collected, the actual yields on large land areas will remain speculation.

Summary

The feral species, Cucurbita foetidissima, the perennial Buffalo gourd, has the potential of becoming a cultivated food crop, producing seed rich in edible oil and protein. It also produces an extensive storage root system rich in starch. It has evolved in the arid regions of North America and is

adapted to growing on arid to semiarid lands which constitute much of the world's land mass, lands now marginal for crop production. Increased support for research for breeding experiment and cultural practices is warranted.

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