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PROXIMATE ANALYSIS OF SONORAN DESERT FOOD PLANTS

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PROXIMATE ANALYSIS OF SONORAN DESERT FOOD PLANTS

by

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STATEMENT BY AUTHOR

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ABSTRACT

The proximate composition (moisture, protein, fat, carbohydrate, crude fiber and ash) for 50 collections of 23 species of Sonoran Desert food plants was determined according to AOAC procedures. Among the items analyzed were cereals, legumes, seeds, green herbage, fruits and flowers, gathered from Arizona and Mexico.

The results indicated that the proximate composition of the same species of plants obtained from different locations had slight variations. Generally, the moisture and carbohydrate content of legumes, corns and wheats analyzed were slightly lower, but the protein and fat content were slightly higher than normal. Most of the seed, green herbage, fruits and flowers analyzed were less well known. The results indicated that these wild plants such as the seed of saguaro and bellota are good sources of protein and oil.

It is recommended that the knowledge regarding utilization of native foods be preserved and that the usage of some of these food plants be continued.

CHAPTER 1

INTRODUCTION

In arid and semi-arid regions where the annual rainfall is small and no stream water is available for irrigation, the natives are forced to use the plants which occur in abundance around them. The Pima and Papago Indians of Southern Arizona, for example, used many wild food plants and native varieties of cultigens up to the late 1940's (Castetter and Bell, 1942), and some of these are still in use today. For these people, major carbohydrate foods are derived from certain seeds, fleshy non-seed fruit parts such as mesocarp tissue, and various storage organs such as thickened stems, roots and tubers. Major sugar sources are from the non-seed portions of fruits, and the important sources of vegetable protein and oil are the seeds themselves.

Although not all of the desert food plant species can be recommended, many others found throughout the continent and formerly of prime importance to native people, are both tasty and of significant nutritional value. It is important, therefore, to present some of these little recognized but potentially valuable plants with the suggestion that, having been used in the past as an important food source for man, these plants should be further investigated as potential modern foods. Some would be satisfactory as they presently exist; others could be significantly improved in quality and yield through selection, hybridization and cultivation. All could add diversity, interest and nutritional value to the diets of people of the world.

The purpose of this study was to determine the proximate composition of several native desert plants formerly used as food by the American Indians with the hope that recognition of their high nutritional quality will help to ensure their survival. In addition, it was intended to provide information about nutritive value of the plants which could help in evaluating such plants either before any selection or breeding procedures or recommending the plants for usage in human diets.

CHAPTER 2

LITERATURE REVIEW

World Population and Man's Dependence on Plants

The rapidly increasing world population has made the production of food in the future a pressing problem. The total world population is approximately 4.5 billion (Langer and Hill, 1982); this number continues to rise, and will climb inexorably in the future (Figure 1).

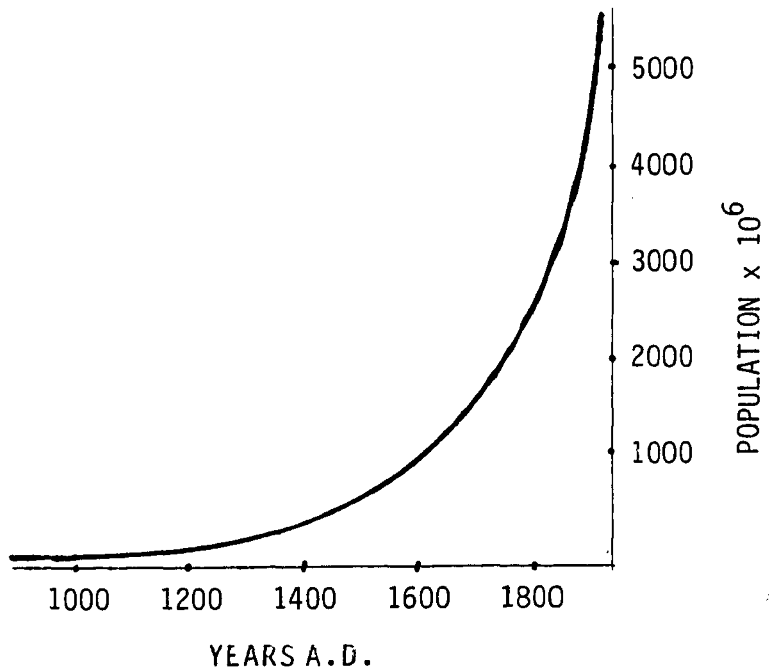

Figure 1. Growth of the world population

This number of people creates enormous demands for food, and it is to plants, one of the few available renewable resources, that people must look to meet this need.

In highly developed countries, people may not always be aware of their dependence on plants, because much of their diet is of animal origin, and Table 1 (Langer and Hill, 1982) shows that only about one-half to one-third of protein intake come directly from plant sources.

Table 1. Proportion of diet which comes directly from plant sources

Land Mass	Calories (%)	Protein (%)
Asia	95	78
Africa	93	79
Europe	81	53
North America	68	30
Oceania	65	34

Some plants do not serve as food directly but rather find their way into the human diet after processing. Apart from their function of providing food, plants have served a great variety of other purposes. Man has always depended upon plants for shelter, fuel, extraction of medicines, chemicals and fibers (Adams et al., 1979). Many plants have been used since the early days of civilization; others have been recognized only in fairly recent times; and there are others which are still waiting for development. Two strategies can be used to meet the enormous need for food plants: either finding more land on which to grow the new crops required by man, or by discovering ways of raising productivity per unit area (Mosse and Bandet, 1983).

Interest in Arid and Semi-Arid Plants

Among the world's most problematical regions from an agricultural standpoint are the arid and semi-arid zones. Although these areas usually offer relatively fertile and moderately textured soils, the universal dearth of water (especially non-saline water) renders them unfit for cultivation of most conventional crops (Felger, 1979). Since the primary resource essential for producing food is land and approximately one-third of the land surface of the world is arid or semi-arid (Goodin and Northington, 1979), it behooves people to look for food plants specifically adapted to dry lands in order to increase food production to keep up with population growth. Some of these plants are wild and untested, and some even poorly identified.

Researchers are beginning to recognize that many such plant species not only exist in the native flora, but also that several have economic as well as agronomical potential. The buffalo gourd, for example, produces substantial yields of vegetable oil, protein, starch and green biomass. It has been utilized by native American Indians for centuries, and with appropriate cultural methods it could become a major new food and forage crop for semi-arid regions. Another arid zone plant, the mesquite tree, while considered a nuisance weed by many, is a productive and useful plant for desert areas. It produces highly nutritious fruits and seeds, requires little water, and as a leguminous tree, it increases soil nitrogen (Felger, 1979).

The interest in agricultural production from vast regions of developing countries that had been considered non-arable in the past, might help reduce the increasing number of humans who waste their lives away in malnutrition and poverty.

Human Use of Sonoran Desert Plants

According to Shreve and Wiggins (1964), the Sonoran Desert, which covers an area of 310,000 sq. km., supports a flora of about 2,500 species of seed plants. About 18 percent of this flora, or approximately 450 species (375 native and 75 naturalized species), were utilized for food by the various native people in the region. More than 10 percent of the 375 edible species have been utilized as major food resources (Felger and Nabhan, 1978).

Highly important among these are two major families, including Cactaceae (cactus family) and Fabaceae (legume family). Castetter and Bell (1942) estimated the aboriginal Pima crops, maize, beans and pumpkins, to comprise only about 50 to 60 percent of the total food supply and thus wild foods were necessary to supplement the diet (especially mesquite, saguaro and cholla cacti). Hesse (1959) reported that only 16 percent of the protein in the Pima Indians' diet came from an animal origin. Even when the supply of cultivated crops was abundant, the Pima gathered native flora, for reasons such as personal preference, ease of access and the continuation of tradition. However, a dietary survey by Reid et al. (1971) indicated that, while some of the older Pima Indians still prepared a few of the traditional foods used by their ancestors, the younger people were eating more contemporary foods. The traditional foods were no longer making a significant nutritional contribution, since chicken, pork, spinach, carrot and potatoes were widely added to their diet. At present, 47 percent of their protein is of animal origin.

About 145 species of cacti occur in the Sonoran Desert (Shreve and Wiggins, 1964), and most of these were used for food by the local people. Some cacti have dry, inedible fruits, while others have fleshy fruit which can be eaten fresh. The fleshy fruits usually contain small seeds. However, the seeds of Opuntia and related genera are not usually edible. The columnar cacti, including the saguaro (Carnegiea gigantea) are still harvested for their fruits. Fifty to one-hundred percent of the fruit is edible; it is usually sweet, and the sugary rich pulp contains many small seeds. The fruit can be consumed fresh, dried or preserved. The seeds are parched and ground into paste (Felger, 1979).

There are about 282 species of legumes known from the Sonoran Desert (Shreve and Wiggins, 1964), and about 40 of these were utilized for food by the native people (Felger, 1979). The beans were the basic food for the Pima Indians, providing almost half of their protein intake (Hesse, 1959). Among the genera which include species of primary significance are Acacia, Cercidium, Olneya, Phaseolus and Prosopis. According to Aykroyd and Doughty (1964), the per-capita daily consumption of legumes within contemporary Indian communities in Arizona and New Mexico is among the highest in the world.

The flora of the Sonoran Desert includes about 167 species of grasses, and the native people utilized about 30 to 35 of these species for subsistence (Shreve and Wiggins, 1964).

The use of traditional foods by most native American Indians declined drastically when the people were relocated to reservations with limited and/or unfamiliar local food resources (Kuhlein et al., 1979); this may also be partly due to increased availability of marketed foods and changing lifestyle.

Proximate Composition and Nutritional Value of Native Foods

Food traditional to pre-industrial native groups is generally regarded as more healthful than the imported, refined food products which are most easily accepted and readily available to people with limited resources. However, little attention has been paid to nutrient composition of traditional native foods, partly because reliable, consistent data are difficult to obtain (especially since traditional food ways are declining), and partly because such studies are of little commercial value (Kuhlein et al., 1979).

Products of saguaro fruit used by the Papago Indians were analyzed by Greene (1936), as shown in Table 2. On a dry weight basis, he found that the whole, air-dried saguaro fruit contained 13.1 percent protein, 9.9 percent fat, 13.4 percent crude fiber and 6.9 percent ash, while the seeds contained 15.8 percent protein, 21.4 percent fat, 28.4 percent fiber and 2.3 percent ash. Apparently the seeds contain higher amounts of protein and oil than do the fruit.

Table 2. Proximate Composition of Several Food Plants (% Dry Weight)

	Moisture	Protein	Fat	Carbo-hydrate	Fiber	Ash	Refe-rence
Cactus							
Opuntia spp. (fresh fruit)	87	0.2	0.3	8	-	-	a
Cereus giganteus (dried fruit)	3.8	13.1	9.9	53	13.4	6.9	a
Cereus giganteus (dried seed)	-	15.8	21.4	-	28.4	2.3	a
Legumes							
Phaseolus lunatus	11	19.7	1.1	64.8	4.4	3.4	b
Phaseolus vulgaris	11	22.1	1.7	61.4	4.2	3.8	b
Pisum sativum	11	22.5	1.8	62.1	5.5	2.6	b
Phaseolus aureus	11	23.9	1.3	60.4	4.2	3.4	b
Vigna unguiculata	16	21.2	1.3	58.2	6.0	3.1	c

References: a. Greene, 1936

b. Aykroyd and Doughty, 1964

c. Meiners et al., 1976

The proximate composition of several species of legumes is also included in Table 2. It was not stated where these plants were obtained, and the values may not be representative of the nutrient content of the same items when obtained from the Sonoran Desert. A study by Nabhan et al. (1980) demonstrated the importance of obtaining plant materials for analysis directly from the ecosystem traditionally exploited by indigenous peoples. The protein content of tepary beans harvested from the traditional Papago floodwater fields was significantly higher than those grown in conventionally irrigated fields. Chemical composition is known to differ from one species to another and even from one cultivation to another; it can also differ between plants of the same variety, according to the circumstances of growth and development. Such differences arise from two main groups of factors: genetic and varietal factors on the one hand, and environmental influence and physiological conditions on the other. Both factors are involved with and interact with one another (Moose and Bandet, 1983).

It appears that all human nutrient needs would be met if a sufficient quantity of food plants were available and if the nutrients were absorbed. Energy-rich carbohydrates are available from beans, fruits of cacti, and other locally abundant desert plants. The diet can be of high protein quality when sufficient overlap occurs between the amino acids of various plant food sources, thereby providing a complete protein. The plants also contain a significant amount of vitamins and minerals; a possible exception might be ascorbic acid when dried foods are eaten after a period of storage. Deficiency of vitamin B_{12} could possibly be a problem when animal food resources are limited.

Acceptance of New Foods

Many factors need to be carefully considered when introducing a new food into the modern marketplace. Like most conventional plants, many of the aboriginal plant foods contain a variety of chemical substances such as oxalates, alkaloids, protease inhibitors, saponins, etc. that could be harmful or even fatal if taken in large doses (Leiner, 1980). Fortunately, the human body is capable of handling small amounts of these chemicals in most instances; as long as the foods containing them are used in moderation as part of a varied, nutritionally balanced diet, they cause no problems.

Some plants contain particularly high concentrations of potentially harmful chemicals and must either be excluded from the diet altogether or be specially treated in some way to remove or reduce the concentration of undesirable compounds. A correct preparation of foods can eliminate or reduce the toxic compounds, and such treatments were often well known to native people. Also, many of these plants could be significantly improved in quality and yield through plant breeding. Certainly any plants introduced into the marketplace would have to be intensively screened to ensure that they do not contain toxic or undesirable substances.

Another possible problem with the use of some indigenous foods is the apparent reluctance of people to try anything new. The fast-food-outlet mentality, where people seem to crave foods that are familiar and predictable, not to mention those that are low in fiber and high in fat, is evidently prevalent in today's society. However, the success of new food items such as soybean products is a good indication that at least a considerable portion of the population would be willing to try some of the new foods, particularly if the nutritional value, availability and economy of these foods could be demonstrated.

CHAPTER 3

METHOD

Sample Preparation

Several species of plants known to be used as food by the American Indians were obtained through Native Seeds/Search and identified by Dr. G. Nabhan from the Office of Arid Lands Studies, University of Arizona. The samples were finely ground in a Wiley mill to pass a 30-mesh screen, yielding 10 g meal each. Samples with high moisture content were freeze-dried before grinding.

Proximate Analysis

Proximate analysis of the meal was run in duplicate according to AOAC (1980) procedures (except for crude fiber). Moisture was determined by drying under vacuum, crude fat content by extraction with hexane in a Goldfish apparatus, crude protein by micro-Kjeldahl (conversion factor is 6.25), and ash content by ashing at 550° C. Fiber was determined by the acid detergent fiber method (Van Soest, 1963). The sample was refluxed in acid detergent solution (2% hexadecyltrimethylammonium bromide dissolved in 1N sulfuric acid) and filtered in a sintered glass crucible. The carbohydrate was calculated by difference. All the results reported were based on the sample as received. The energy content (kcal/100g) was calculated by the following formula:

energy = % protein x 4 + % carbohydrate x 4 + % fat x 9

Tables 3.1 to 3.4 list the plants analyzed for proximate composition and the source from which they were obtained.

Table 3.1. Cereals Analyzed for Proximate Composition

Scientific Name	Common Name/Description	Source	Log No.
Zea mays	Papago 60-day flour corn	Papago Indian Reservation, AZ San Pedro Villaga	1376
Zea mays	Chapalote pop flint corn	Sinaloa, Mexico	1377
Zea mays	Papago-Pima flour corn	Salt River Reservation, AZ	1380
Zea mays race reventador	Maiz Reventador pop corn	Santiago, Sonora, Mexico	1392
Zea mays	Eudeve Pima flour corn	Onavas, Sonora, Mexico	1403
Zea mays	Eudeve Pima sweet corn	Onavas, Sonora, Mexico	1405
Zea mays	Hopi sweet corn	Hopi Indian Reservation, AZ	1427
Zea mays	Mountain Pima sweet corn	Nabogame, Chihuahua, Mexico	1432
Zea mays	Mountain Pima little white corn	Las Varas, Chihuahua, Mexico	1433
Zea mays	Mountain Pima maiz blando flour corn	Las Varas, Chihuahua, Mexico	1434
Zea mays	Mountain Pima dark flour corn	Las Varas, Chihuahua, Mexico	1435

Table 3.1. Continued

Scientific Name	Common Name/Description	Source	Log No.
Zea mays	Mountain Pima cristalino de Chihuahua flint corn	Las Varas, Chihuahua, Mexico	1436
Zea mays	Mountain Pima yellow corn	Nabogame, Chihuahua, Mexico	1437
Zea mays	Mountain Pima 'crying' multi-colored flour corn	Nabogame, Chihuahua, Mexico	1438
Zea mays	Mountain Pima red-purple corn	Nabogame, Chihuahua, Mexico	1439
Triticum aestivum	tortilla wheat	Las Varas, Chihuahua, Mexico	1406
Triticum aestivum	White Sonora wheat	Cucurpe, Sonora, AZ	1408
Triticum aestivum	Papago White Sonoran wheat	Freshal Village, AZ	1412

Table 3.2. Legumes Analyzed for Proximate Composition

Scientific Name	Common Name/Description	Source	Log No.
Pisum sativum	Papago pea	Mesa, AZ	1378
Vigna unguiculata	black eye pea	Papago Indian Reservation, Big Fields Village, AZ	1379
Vigna unguiculata	black eye pea		1443
Phaseolus lunatus	Pima lima bean	Gila River Indian Community, AZ	1381
Phaseolus vulgaris	morado/fryo	Sonora, Mexico	1391
Phaseolus vulgaris	morado/Sonoran pink bean	Ures, Sonora	1409
Phaseolus vulgaris	pinto bean	Romero Field, Pinacate, Sonora	1441
Phaseolus vulgaris	common bean		1424
Phaseolus vulgaris	common bean		1425
Phaseolus acutifolius	mottled tepary bean		1415
Phaseolus acutifolius	beige tepary bean	Pinacate, Sonora	1404
Phaseolus filiformis	wild desert bean	Romero Field, Pinacate, Sonora	1428
Phaseolus acutifolius latifolius	wild tepary bean		1429
Phaseolus coccineus	Tarahumara runner bean (purple)	Chihuahua, Mexico	1440
Phaseolus coccineus	Tarahumara runner bean (white)	Chihuahua, Mexico	1426

Table 3.3. Seeds Analyzed for Proximate Composition

Scientific Name	Common Name/Description	Source	Log No.
Cucurbita moschata	sequalcha squash seed	Tucson, AZ	1396
Cucurbita mixta	seed of Papago squash	San Xavier or San Pedro Village, Papago Indian Reservation, AZ	1382
Quercus emoryi	bellota, acorn		1394
Amoruexia palmatifida	saiya seed	Ruby, AZ	1407
Amaranthus hypochondriacus	grain amaranth	Valley of Mexico, D.F., Mexico	1442
Hyptis suaveolens	warihio conivari seed	Rancho Terrero, Sonora, Mexico	1413
Hyptis suaveolens	warihio conivari seed		1444
Panicum sonorum	warihio panic grass	Rio Mayo Watershed, Sonora-Chihuahua	1414
Helianthus annuus (seed)	Hopi sunflower	Hopi Indian Reservation, AZ	1417
Helianthus annuus (hull)	Hopi sunflower	Hopi Indian Reservation, AZ	1416
Cereus giganteus	seed of saguaro cactus	Santa Rosa, Papago Indian Reservation, AZ	1390

Table 3.4. Green Herbage/Fruits/Flowers Analyzed for Proximate Composition

Scientific Name	Common Name/Description	Source	Log No.
Opuntia violacea	flower buds of purple prickly pear	Tucson, AZ	1395
Rumex hymenosephalus	canaigre	Sonora, Mexico	1383
Capsicum annum var. aviculare	chiltepin	US/Mexico border	1393
Chenopodium berlandreri var. nuttalliae	huazontle greens	Tucson, AZ	1398
Cucurbita moschata	flesh fruit of squash	Tucson, AZ	1396
Allium spp.	Papago onion bulb	Tucson, AZ	1410

Table 4.1. Proximate Composition of Cereals (as Collected)

Cereals	Energy kcal/100g	Moisture	Protein	Fat	Carbo-hydrate	Fiber	Ash
Zea mays							
Papago 60-day flour corn	364	10.5	9.9	4.4	71.2	2.3	1.6
Chapalote pop flint corn	375	8.3	11.2	4.4	72.7	1.8	1.6
Papago-Pima flour corn	377	6.8	12.1	4.3	72.4	2.7	1.7
Maiz Reventador pop corn	373	7.5	11.6	4.2	72.3	2.7	1.7
Eudeve Pima flour corn	373	8.3	11.2	4.3	72.3	2.6	1.3
Eudeve Pima sweet corn	356	11.4	10.7	4.0	69.3	2.9	1.7
Hopi sweet corn	363	9.7	9.8	4.1	71.7	3.0	1.7
Mountain Pima sweet corn	388	3.9	9.5	4.7	76.9	2.8	2.2
Mountain Pima white corn	386	4.2	10.7	3.9	77.1	2.9	1.2
Mountain Pima flour corn	389	4.1	10.4	4.1	77.7	2.4	1.3

Table 4.1. Continued

Cereals	Energy kcal/100g	Moisture	Protein	Fat	Carbo-hydrate	Fiber	Ash
Mountain Pima dark flour corn	393	4.2	12.2	4.9	75.0	2.4	1.3
Mountain Pima cristalino de Chihuahua flint corn	390	3.8	11.5	3.8	77.4	1.8	1.7
Mountain Pima yellow corn	390	4.5	10.4	4.2	77.6	2.0	1.3
Mountain Pima crying multicolored flour corn	391	3.5	9.9	4.2	78.4	2.8	1.2
Mountain Pima red-purple flour corn	391	3.9	12.1	4.4	75.8	2.7	1.1
Triticum aestivum							
tortilla wheat	354	9.0	13.1	1.8	71.4	2.9	1.8
White Sonora wheat	366	7.3	13.3	2.3	73.1	2.4	1.6
Papago White Sonora wheat	359	7.5	13.8	2.3	70.8	3.4	2.2

Table 4.2. Proximate Composition of Legumes (as Collected)

Legumes	Energy kcal/ 100g	Moisture	Protein	Fat	Carbo-hydrate	Fiber	Ash
Pisum sativum (Papago pea)	352	7.8	26.3	1.8	57.7	3.6	2.8
Vigna unguiculata (black eye pea)	335	8.9	23.6	2.1	55.3	6.7	3.4
Vigna unguiculata (black eye pea)	331	8.6	24.3	1.8	54.3	7.8	3.2
Phaseolus lunatus (Pima lima bean)	324	9.1	19.9	1.6	57.5	7.1	4.8
Phaseolus vulgaris (morado bean)	337	6.5	23.3	1.8	56.9	7.2	4.3
Phaseolus vulgaris (Sonora pink bean)	328	8.4	224.	1.2	56.9	7.3	3.8
Phaseolus vulgaris (pinto bean)	333	7.4	19.6	1.9	59.4	7.7	4.0
Phaseolus vulgaris (common bean)	323	10.5	20.2	2.1	55.9	7.5	3.8
Phaseolus vulgaris (common bean)	328	9.1	22.8	1.8	55.2	6.8	3.3
Phaseolus acutifolius (mottled tepary bean)	341	6.7	25.6	2.1	54.8	6.8	4.0
Phaseolus acutifolius (beige tepary bean)	328	9.3	24.9	1.9	52.8	7.8	3.3

Table 4.2. Continued

Legumes	Energy kcal/ 100g	Moisture	Protein	Fat	Carbo-hydrate	Fiber	Ash
Phaseolus filiformis (wild desert bean)	331	8.1	26.1	2.1	52.0	6.7	5.0
Phaseolus acutifolius var. *latifolius* (wild tepary bean)	328	10.1	23.8	2.2	53.3	6.6	4.0
Phaseolus coccineus (purple runner bean)	345	5.1	24.1	1.9	57.8	6.9	4.2
Phaseolus coccineus (white runner bean)	331	10.2	23.4	2.1	54.5	6.7	3.1

Table 4.3. Proximate Composition of Seed (as Collected)

Seeds	Energy kcal/ 100g	Moisture	Protein	Fat	Carbo- hydrate	Fiber	Ash
Cucurbita moschata (squash seed)	161	66.2	8.5	5.0	10.4	6.4	3.5
Cucurbita mixta (squash seed)	361	5.1	21.5	20.8	21.9	26.3	4.4
Quercus emoryi (acorns)	474	2.6	21.1	24.8	41.6	7.5	2.4
Amoruexia palmatifida (saiya seed)	342	7.9	13.4	12.7	43.5	18.8	3.7
Amaranthus hypochondriacus (grain amaranth)	366	8.4	14.7	7.8	59.2	7.7	2.2
Hyptis suaveolens (conivari seed)	289	5.1	5.8	3.7	58.0	23.2	4.2
Hyptis suaveolens (conivari seed)	271	7.2	5.0	3.4	55.2	25.2	4.0
Panicum sonorum Sonoran panic grass	247	7.7	8.9	4.6	42.5	31.2	5.1
Helianthus annuus (Sunflower seed)	514	4.3	22.2	33.3	31.3	4.1	4.8
Helianthus annuus (Sunflower seed hull)	125	6.5	3.8	1.4	24.4	61.0	2.9
Cereus giganteus (Saguaro cactus seed)	429	4.1	21.9	20.1	40.0	11.9	2.0

Table 4.4. Proximate Composition of Green Herbage/Fruits/Flowers (as Collected)

	Energy kcal/ 100g	Moisture	Protein	Fat	Carbo-hydrate	Fiber	Ash
Opuntia violacea (purple prickly pear flower buds)	55	68.1	0.8	0.4	12.0	12.3	6.4
Rumex hymenosephalus (canaigre)	259	5.2	4.6	0.8	58.4	24.6	6.4
Capsicum annum var. aviculare (chiltepin)	341	4.5	13.7	10.9	46.9	19.7	4.3
Cucurbita moschata (squash flesh)	47	79.1	1.8	0.2	9.5	8.5	0.9
Chenopodium berlandreri var. nuttalliae (huazontle greens)	44	81.6	6.0	0.9	2.9	4.4	4.2
Allium spp. (Papago onion bulb)	36	88.4	2.6	0.3	5.7	2.3	0.7

CHAPTER 5

RESULTS AND DISCUSSION

Proximate Composition of Food Plants

Data on proximate composition (moisture, protein, fat, total carbohydrate, crude fiber and ash) for 50 collections of 23 species of Sonoran Desert food plants are given in Tables 4.1 to 4.4. The results reported were based on the sample as received. Several of these plants, including corn, wheat and legumes, are well known and extensively cultivated crops which have long served as important sources of protein and oil in the diets of people throughout the world. For these plants, the analysis was only to show whether the arid conditions and sources under which they were obtained can affect their proximate composition. Unlike most other crops, corn can be grown in a wide variety of climates and on very diverse kinds of soils, as indicated by the geographical distribution of their production. Of the 50 different kinds of food plants analyzed, only a few are not popular as agricultural crops. However, this preliminary analysis was not extensive enough to enable one to draw a definite conclusion as to whether those less popular plants have the potential to be new agricultural crops in the future. To become a major crop in arid lands, the plants should be chosen to fit the arid environment, rather than the environment being modified to suit the crops.

Comparison between the values obtained in this analysis with other published data for the same or related species may be inappropriate since, as mentioned earlier, many differences between values could be due to genetic variations, stage of maturation, and agricultural conditions such as temperature, rainfall, methods and seasons of cultivation, and nature of the soil. Nevertheless, the reported values provided a reasonably good estimate of the chemical composition of the plants. According to Felger (1979), the seeds of arid land plants tend to be small, but they are high in protein and/or oil content.

Moisture

Moisture values for cereals and legumes were generally lower than previously published data, which normally range between 10 and 12% moisture (Aykroyd and Doughty, 1964). Tables 4.1 and 4.2 illustrate that the moisture content of cereals and legumes in this analysis ranged between 3 to 10% and 5 to 9% respectively. The lower values were expected, since the samples had already been dried prior to moisture determination. Besides, some of the samples were stored a few months prior to analysis. According to Meiners et al. (1976), the moisture content of dried legumes is generally affected by the relative humidity of the surrounding atmosphere at harvest and during storage. The difference in moisture content between the data reported in Table 4 and the data from other sources may well have been due to the past environments and sources of samples.

Protein

Protein values determined for legumes in this study were generally in agreement with, but slightly higher than, those found in other studies (Meiners et al., 1976; Aykroyd and Doughty, 1964). These slightly higher values might be partly explained by the lower moisture values found in the current study. Besides, protein content among legumes species can vary as much as 15 to 40% (Earle and Jones, 1962), with common varieties displaying 20 to 30% protein.

Diversity in protein content may be influenced by genetic and environmental factors, even though racial differences were not evident in teparies, in which white-seeded tepary protein values were almost identical with brown seeded types (Nabhan et al., 1980). However, the environmental influence of irrigation regimes upon protein contents was obvious. Traditional floodwater farming techniques were found to produce beans with significantly higher protein content than those grown off-reservation in conventionally irrigated fields.

Table 4.2 indicates that the protein content of eight different species of legumes analyzed ranged between 19.6 and 26.3 percent. The white- and purple-seeded types of *Phaseolus coccineus* contain 23.4 and 24.1% protein respectively. It seems that their protein levels were almost identical. Of five samples of *Phaseolus* vulgaris obtained from different locations, the protein content has little variation. It ranged between 19.6 and 23.3% in pinto beans from Pinacate, which contain the lowest amount, while the samples from Sonora, Mexico have the highest protein content. Among the legumes, the Papago peas (Pisum sativum) from Mesa, Arizona had the highest protein content. The protein content of peas appears to be highly variable and is influenced by both genetic and environmental factors (McLean et al., 1974). They reported that pea protein contents were increased by increasing soil nitrogen and phosphorus and decreasing soil potassium. The protein content also increases at high growth temperatures. Most of the difference in protein content in peas was accounted for by starch (Reichert and Mackenzie, 1982).

The protein content of cereal grains varies, but in general these grains contain less than 20% protein. Fifteen samples of corn and three samples of wheat obtained from different locations contain protein ranging between 9.5-12.2% and 13.1-13.8% protein respectively. The protein content of the three wheat samples did not vary greatly from the average value usually found in wheat. The protein of wheat has been shown to vary widely among different varieties grown under different environmental conditions. The potential to deposit a high proportion of protein nitrogen in the endosperm is controlled genetically, but the amount actually deposited is greatly influenced by environment and agronomic management (Arnon, 1972).

The protein content of some corn samples analyzed was slightly higher than usual. Papago-Pima flour corn from Tucson, Mountain Pima dark flour corn, and Mountain Pima red purple corn from Chihuahua, Mexico contain more than 12% protein. A direct relationship exists between the amount of nitrogen applied to the soil and the content of protein in corn (Arnon, 1972).

The data in Table 4.3 show that the seeds of squash (Cucurbita mixta) and bellota have relatively higher protein content (21.5 and 21.1% respectively) than other seeds in the same table. However, the seed of bellota is encased in a stony endocarp which makes it difficult to free the seed. This characteristic might be inconvenient for large-scale consumption. Amaranth grain also has a relatively high protein content (14.7%).

The high protein content of Capsicum annuum might be contributed mainly by the seeds, since they were not separated prior to analysis. However, spices do not make a significant nutritional contribution to the diet; their only important contribution is flavor.

The significance of fruits and vegetables as a source of protein is generally small compared with that of cereals and legumes. As shown in Table 4.4, green vegetables such as huazontle (Chenopodium berlandreri) contain less than 10% protein. However, green vegetables are generally richer in protein than are fruits, for example swuash, which contains less than 2% protein. The chemical composition of leaves, unlike that of seeds, is generally fairly uniform, especially with regards to the protein content. Leaf protein, when correctly prepared, has a high biological value, suitable for human consumption.

Crude Fat

Generally, crude fat levels of legumes, fruits and vegetables were negligible in all samples. For these foods, fat may only contribute significantly to the nutritive value as a carrier of fat-soluble vitamins. The vegetable oil of legumes contains an average level of 70% unsaturated component, some of which is essential to the human diet. Of eight legume species analyzed, the fat content ranged between 1.2 and 2.2 percent. These values are commonly found in legumes and are in good agreement with other previous data (Aykroyd and Doughty, 1964). Vigna unguiculata from the Pima Indian Reservation contains 2.1% fat, while the same species from other sources contains only 1.8% fat. Of five Phaseolus vulgaris varieties obtained from different locations, fat content varied 0.9%, ranging between 1.2 and 2.1 percent.

Items classified under green herbage or fruits in Table 4.4 contain less than 1% fat (except for Capsicum annuum). In vegetables and fruits, fat is largely confined to the cytoplasmic layers, in which it is especially associated with the surface membrane.

In contrast, seeds (Table 4.3) contain substantial quantities of vegetable fats, which are major commodities of industry and world trade. Hopi sunflower seeds contain 33.3% fat, slightly lower than the value usually found in sunflower seeds. A considerable quantity of fat also can be found in the seeds of saguaro, Cucurbita mixta and bellota, which contain 20.1, 20.8 and 24.8% fat respectively. However, the seed of Cucurbita moschata contains only 5.0% fat. Values for oil content in seeds of cucurbita, as analyzed by several investigators, have generally been near 30 percent. In some countries, cucurbita oil has been used for cooking purposes. Unlike most other cereals, grain amaranth, which has recently become popular, also contains a significant amount of fat (7.5%). Amoreuxia palmatifida also contains relatively high amounts of fat: 12.7% of the seed weight.

Additional oilseed crops adapted to desert conditions could provide an important supplement to the present supply of vegetable oils. Furthermore, the protein rich by-product of the oil extraction process is becoming increasingly important as a dietary supplement for humans and livestock.

Corn contains more oil than most other cereals. The average fat content for 15 corn samples in Table 4.1 was 4.3 percent. However, Mountain Pima Cristalino de Chihuahua flint corn and the

Mountain Pima white corn from Mexico contain 3.8 and 3.9% fat respectively, the lowest among the corns analyzed. Higher fat content was found in the Mountain Pima red purple flour corn, the Mountain Pima sweet corn, and the Mountain Pima dark flour corn from Mexico, which contain 4.4, 4.7 and 4.9% fat respectively. Of three wheat samples from different locations, fat content ranges between 1.8 and 2.3%; this was similar to the value commonly found in wheats.

Crude Fiber

Crude fiber is the residues after food has been treated in the laboratory with solvent, hot acid and hot alkali. It may represent as little as one-seventh of the total dietary fiber of the food, which includes hemicellulose, pectic substances, gums, mucilages, and certain other carbohydrates, as well as lignin and cellulose (Trowell, 1976). Recent interest in dietary fiber has arisen from epidemiological observations linking the lack of plant fiber in the diet with the prevalence of certain degenerative diseases in industrial societies, such as diverticulosis, diabetes, coronary heart disease, and colon cancer. Several sources of dietary fiber such as purified cellulose, wheat bran and pea hulls have been incorporated into food products as fiber supplements (Sosulski, 1982). Various foods recognized as excellent sources of dietary fiber include fruits, raw vegetables, whole grain products and leguminous seeds.

Of the samples evaluated, the sunflower hull was a concentrated source of crude fiber. The value obtained (61.0%) was in agreement with published data for sunflower seed hull (Dreher and Padmanaban, 1983). Dreher and Padmanaban showed that sunflower seed hull flour has potential as a dietary fiber supplement since there was no significant difference in aroma of muffins made with hull flour or wheat bran, although differences did exist in appearance, flavor and texture. Hulls represent a large proportion of sunflower seed and may present storage or disposal problems if sufficient uses are not found.

In most legume species, crude fiber content was relatively high, comprising 3.6 to 7.8% of the seed weight. Among the legumes analyzed, Phaseolus vulgaris had a high crude fiber content, ranging between 6.8 and 7.7 percent. Pisum sativum contains 3.6% fiber, the lowest among the legumes.

Corn contains less fiber than most other cereal grains. Table 4.1 illustrates that the fiber content in fifteen corn samples ranged between 1.8 and 3.0%; Hopi sweet corn contains the highest, and flint popcorn from Arizona and Chihuahua, Mexico contains the lowest.

Wheat contains slightly higher fiber than corn. Papago White Sonora wheat contains 3.3% fiber, while tortilla wheat contains 2.9% fiber.

The fiber content of grain amaranth was 7.8%, three to four times that of common cereals. The seed of *Cucurbita mixta* contains 26.3 percent. The fiber content in green herbage or fruit was also high, ranging between 8.5% in the flesh of *Cucurbita moschata* and 19.7% in *Capsicum annuum* (Table 4.4).

Ash

It is generally recognized that people consuming grain-based diets need additional essential minerals in the form of animal foods or dietary salts to maintain physiological homeostasis, since fiber and phytate in grains can form complexes with dietary minerals thus decreasing their absorption in the digestive tract. In grains, minerals tend to be concentrated in bran and germ; therefore the milling process can significantly reduce the amount of minerals.

Of eight legume species analyzed, the ash content was relatively high, ranging between 2.8 and 5.0% (Table 4.2). The mineral contents vary greatly with the mineral composition of the soil, fertilizer practices and other agricultural factors (Arnon, 1972). Ash content was higher in *Phaseolus filiformis*, *Phaseolus lunatus* from Gila Indian Community and *Phaseolus vulgaris* from Mexico, which have 5.0, 4.8 and 4.3% ash respectively. *Pisum sativum* contains only 2.8% ash.

The ash content in corn and wheat was lower than that in legumes. The ash content in fifteen corn samples from different locations did not vary much. The lowest value was found in Eudeve Pima sweet corn from Sonora, Mexico, which contains 1.3% ash. Papago White Sonora wheat contains 2.2% ash, while White Sonora wheat contains 1.6%. It seems that the values did not vary much.

Fruits and vegetables contain a wide range of mineral elements and make an important contribution to human nutrition. The flowers of Opuntia violacea and Rumex hymenosephalus each contain 6.4% ash (Table 4.4). Like other grains, the seeds of cucurbita, bellota, Amoreuxia palmatifida, Panicum Sonorum and Hyptis sauveolens contain ash in the range between 2.2 and 5.1 percent.

Carbohydrate

The largest component in legumes and cereals is carbohydrates, of which starch is the most significant nutritionally. Starch levels in legumes typically exceed 50% of the dry matter present in the seed, which is generally well utilized and provides most of the caloric value of these food legumes. Table 4.2 shows that carbohydrate content of legumes varied from 52.0 to 59.4%. These values were slightly lower than previous data (Aykroyd and Doughty, 1964). Legume starches were intermediate in digestibility between highly digestible cereals and poorly digestible root or tuber starches (Hellendoorn, 1973). Table 4.1 indicates that more than 70% of dry matter in corn and wheat was composed of carbohydrate.

Carbohydrate also was the largest component in green herbage and fruits, but in oilseed such as sunflower seed, carbohydrate content was less than 30 percent.

CHAPTER 6

CONCLUSION

Based on the present study, conclusions regarding the proximate composition of desert food plants are:

1. The same species of plants obtained from different locations give slightly different values in proximate composition.
2. With appropriate cultural methods, the extensively cultivated crops for arable regions, including corn, wheat and legumes, could become major crops in arid and semi-arid regions, since the arid environment did not decrease the proximate composition of these plants. In fact, for some samples of desert plants, protein and oil content were slightly higher than normal values.
3. Several less well known plants traditionally harvested by the American Indians, such as the seed of saguaro cactus and bellota, contain high amounts of protein and fat. These plants may not only contribute significant proportions of recommended daily allowances, but they can also be further processed to yield vegetable protein and oil.

The continuing use of food plants not only improves the nutritional intake, and thus the nutritional status, of the local people, but it also provides inexpensive and easily obtainable sources of foods.

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