Comparison of Potential Staple Crops

by Ronald L. Conte Jr.

Introduction

This article is essentially a set of charts of data, showing which crops produce the most protein, the most dietary fat, the most carbs, and the most kilocalories, per hectare per year, along with explanatory notes. As I explain in my article "Comparison of World Staple Crops", the best way to take account of the land and time resources in the world agricultural system is to analyze crops by the macronutrients produced per hectare (2.471 acres) and per year. Otherwise, a crop might seem to be more productive that it is.

For example, the oil palm tree produces 3524 kg of palm fruit oil per hectare per crop, while chufa (tigernut) produces 1920 kg of oil per hectare per crop (low yield). But a crop of chufa takes up the land for only 4 months, while the palm fruit tree occupies the land for 12 months of the year (like all tree crops). When we take into account the amount of oil produced per month, palm fruit oil provides 294 kg of oil per month, while chufa provides 480 kg of oil per month. And that latter figure is for a low yield of chufa. The high yield is 3360 kg of oil per crop, which is 840 kg of oil per month.

Since much of the data that we have on the world agricultural system is by year, we can express the productivity of a staple crop per hectare-year by multiplying the per month figure by 12. Even though most crops have a growing season of less than 12 months, this figure is still useful, because it allows us to see which crops are the most efficient use of land and time resources in order to produce macronutrients and kilocalories for the world population.

Chart Data

All of the charts used in this article are simply different versions of the same chart, ordered as to which plants produce the most protein, or the most fat, or the most carbohydrates, or the most total kilocalories. The main chart, from which each of these macronutrient charts is derived, has the crops in alphabetical order.

See the Microsoft Excel spreadsheet (.xls and .xlsx) for Chart 1: A to Z
and the other 5 Charts in PDF and PNG format here:
http://www.gardeningplaces.com/articles/

Chart 1: A to Z
Chart 2: Protein Crops
Chart 3: Dietary Fat Crops
Chart 4: Carbohydrate Crops
Chart 5: Refined Sugar Crops
Chart 6: Calorie Crops

This one comprehensive chart is available in Microsoft Excel format. It is, in a sense, the "raw data" from which the other charts are drawn. It has 184 numbered rows, and 17 columns designated A through Q, for 3,128 data cells (minus 3). The row for "pumpkin seed + flesh" has three empty data cells because that listing is calculated by adding the data from two separate listings: pumpkin flesh

and pumpkin seeds. So the three cells giving the percent of each macronutrient do not apply. The first two rows in the chart are headers detailing the content of each column. These rows are labeled beginning with "1-" and "2-" so that sorting will keep those rows at the top.

The 5 other charts are derived from the A to Z chart, with the crops in order by which plants provide the most protein, or the most dietary fat, or the most carbs, or the most total calories (for protein, fat, and carbohydrates combined) per hectare-year. The fifth chart lists only those crops that are, or might potentially be, a good source of refined sugar. For this chart, the total sugar content includes only sucrose, glucose, and fructose; it excludes complex carbs, and indigestible sugars.

The 5 derived charts are shortened, to list only the top 20 or so most productive crops for a macronutrient or total calories or refined sugar. The derived charts are also shortened, removing some listings, because some crops have multiple listings for different yields, or different plant parts used for food. You should download the comprehensive chart and work from it when considering the nutritional productivity of various crops.

Sometimes a crop has more than one listing, for various reasons. Some crops are considered as possible candidates for a Protein Concentrate (PC) crop. Other crops have more than one plant part that is used for food. Still other crops have variable yields, and so there is one listing for a high yield and another for a low yield.

Protein Concentrate is an extract of protein (possibly also with some carbs) that excludes most of the fiber and water in the crop. This approach makes the protein much more digestible and removes anti-nutritional factors. It is one way to obtain a high yield of edible protein from certain types of crops, especially leaf crops.

The first row of the chart has the labels for each of the columns of data. The second row gives the units for that data. The units used in the chart are tonnes (t), which always indicates metric tonnes (1 tonne = 1000 kg), and kilocalories (kcal), which is called 'calories' in common parlance. A hectare (ha) is 2.471 acres of land. The FAOSTAT data reports yield in hectograms (hg) per hectare (which is the same as grams per 100 square meters), but this value has been converted to kg/ha for this chart. Yields from other sources, when given in lbs/acre were converted to kg/ha by multiplying by a factor of 1.12085.

The first column (column A) is the name of each staple crop. Sometimes there is an additional specification, such as high or low yield, or PC (indicating the crops is being analyzed as a possible source of protein concentrate).

The second column (column B) is the yield in kilograms per hectare for one season of the crop. The source of the yield is usually the FAOSTAT database and either the USA data or world data for that crop. More than a few crops are not listed in the FAO database, or at least do not have a yield there (e.g. oil crops). See the endnotes, organized by crop name, for the source of the yield.
FAOSTAT, the agricultural and statistical database of the U.N.'s Food and Agricultural Organization:
http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor
See the FAOSTAT metadata for a description of the way that the FAO categorizes each crop:
http://faostat.fao.org/site/384/default.aspx

Yields in lbs/acre, in various sources of data, have been converted to kg/ha by multiplying by a factor of 1.12085
2.4710538147 (number of acres in hectare)
divided by
2.2046226218 (number of pounds in kilogram)
= 1.12085
Multiply lbs/acre by 1.12085 to convert to kg/ha (just over 12% higher), or divide kg/ha by 1.12085 to convert to lbs/acre.

The third column (column C, labeled '%') is an adjustment factor to account for the hulling, drying, or other processing of the crop, which then reduces the weight of the yield in the second column. The nutritional data for each macronutrient is from the USDA Nutrient Database (SR24), which is for table-ready food. The FAO yield data is typically the field weight, or the weight after minimal processing. When the value is 1.00, the production quantity was not reduced. For example, "beans dry" is data reported for the beans already hulled from the pods, cleaned, and dried, so no reduction is needed. By comparison, "rice paddy" is reduced to 65% of the yield due to losses when the rice is milled (to make white rice from 'rough rice'). Data for various types of oil is typically not reduced since the quantity reported is for the oil, not the oilseed. Peanuts, almonds and other nuts/seeds are reduced significantly, due to the removal of the shell.

The source of the adjustment factor varies. In many cases, the USDA Nutrient Database (SR24) has a food description that includes "Refuse", which is the inedible or not typically eaten portion of the food, such as stems, peelings, parings, shells, etc. For example, the SR24 data for "Beans, snap, green, raw" adds this note: "Refuse: 12% (Ends, strings, trimmings)". Therefore, the yield was reduced by 12% (i.e. multiplied times 0.88). For the source of any particular adjustment factor, see the endnotes, organized by crop name.

The fourth column (column D, labeled 'adjusted') is the result of multiplying the yield by the adjustment factor. This adjusted yield is then used in the data to the right in each row, to calculate the total macronutrients and calories provided by the adjusted yield for each food crop.

The fifth, sixth, and seventh columns (E, F, G) are the percent of each macronutrient (protein, fat, and carbohydrates) found in the food crop. This data is usually taken from the USDA Nutrient Database (SR24) or (SR25), unless otherwise stated in the endnotes.

Most of the essential amino acid profiles for the protein content of each crop, found in the endnotes, are from BitterPoison.com, a website that offers an analysis of essential amino acids by comparison with the ideal essential amino acid values established by the National Academy of Sciences' Institute of Medicine (IOM). That ideal is then compared to the essential amino acid data from an older version of the USDA National Nutrient database (prior to SR23). When a food was not found in the BitterPoison database, see the endnotes (organized by crop name) for the source of the essential amino acid analysis.
http://www.bitterpoison.com/protein/

When other sources were used, the author performed the same type of analysis as found at BitterPoison.com, giving each essential amino acid a score based on a comparison with the ideal values of the IOM. A score of 1.00 indicates that the food provides 100% of the IOM ideal amount of that essential amino acid as a percent of total protein. The three essential amino acids that are most likely to be deficient in any real-world diet are: lysine, methionine, tryptophan. For this reason,

these three essential amino acids have their score listed in the endnotes of each protein crop. Other essential amino acids have their scores listed only if the score is low.

The eighth column (H) is the fiber content of the crop, which is needed to calculate the calories from carbohydrates in the food, since most sources include indigestible fiber within the number of grams of carbohydrates. Unless otherwise noted, the fiber content is from the USDA National Nutrient Database.

The ninth column (I) is the time to harvest, i.e. the length of the growing season, for each crop, in months. Tree crops are listed as 12 months because they take up the land continually, 12 months of the year. Other crops are given a time in months as an estimate of the typical growing season for a commercial crop of that plant. Time to harvest was typically estimated from the notes for various cultivars of each crop, as found in the Seed Savers Exchange Yearbook 2011. This SSE seed catalog has thousands of cultivars, most with notes about the time to harvest. When time to harvest was taken from other sources, this is noted in the endnotes.

The tenth, eleventh, and twelfth columns (J, K, L) give the productivity of the crop for each macronutrient (protein, fat, and carbohydrates) on the basis of kilograms per hectare-year. A tree crop has a 12 month season, so the value for the productivity per hectare-crop and per hectare-year is the same. For other crops, the value per hectare-year is determined by the following formula:
adjusted yield (kg/ha-crop) * percent of the macronutrient * 12 months/year
divided by the time to harvest (months/crop)
equals amount of the macronutrient (kg/ha-year)
This formula gives us the productivity of the crop, i.e. how efficiently the plant uses time and land resources to produce macronutrients. However, please note that the calculation for carbohydrate content (L) subtracts the percent of fiber in the food from the percent of total carbohydrates (percent carbs - percent fiber) before multiplying to obtain the macronutrient yield for carbs. This subtraction is necessary because fiber is a carbohydrate, but it is not used for energy by the body.

The thirteenth column (M) is the total calories from protein, fat, and carbohydrates produced by the crop, in terms of kcal per square meter per year. This value is determined from the information in the previous columns, according to this formula:
total protein in kg/ha-yr times 3870 (which is the number of calories in 1000 grams of protein at 3.87 kcal/gram)
plus total fat in kg/ha-yr times 8840 (which is the number of calories in 1000 grams of vegetable oil at 8.84 kcal/gram)
plus total carbs in kg/ha-yr time 3870 (which is the number of calories in 1000 grams of carbs at 3.87 kcal/gram)
all divided by 10,000 to convert 'per hectare' to 'per square meters'.

The calculation of kilocalories per square meter per year uses the following values for kcal per kilogram of:
protein, 3870 kcal;
fat, 8840 kcal;
carbs, 3870 kcal.
The basis for these numbers is explained in my book, *Hunger Math: world hunger by the numbers*, as follows:

The conversion from kcal to grams for carbs is based on the amount of calories in 100 g of granulated sugar in the USDA Nutrient Database (SR24). At 387 kcal per 100 grams, sugar has 3.87 calories per gram. This food and value is chosen as an approximation, since the calories for each gram of a carbohydrate source vary depending on the food. This value, called the carbohydrate factor, can range from 4.16 for rice, to 4.03 for cassava, to 3.57 for beans. The value for sugar, 3.87, is also the average of a typical high value (rice, 4.16) and a typical low value (beans, 3.57). To find the specific value for any food, go to the USDA Nutrient database, search for the particular food, and then click on "Full Report" and find the "Carbohydrate Factor" (USDA National Nutrient Database for Standard Reference, SR24;
http://ndb.nal.usda.gov/ndb/foods/list

The conversion factor from kcal to grams for protein can be found by looking up a food in the USDA database, and clicking through to the "Full Report" for the "Protein Factor". A value of 4.27 is typical for high quality protein sources, such as meat, poultry, fish, and cheese. Plant sources of protein have a lower protein factor. Rice has a protein factor of 3.82. Chickpeas, soybeans, and similar sources of protein: 3.47. The rough average of the high and low numbers is 3.87, the same number as for carbohydrates.

The conversion factor for fat also varies based on the source of the fat. Meat, poultry, and fish have fat conversion factors of just over 9, and dairy fat has a conversion factor of 8.79 (calories per gram). But the most common source of dietary fat, vegetable oil, has a conversion factor of 8.84 kcal per gram of fat. So that is the value that we will use here. It is intermediate between the high and low numbers, and it is the exact value for vegetable oil (cooking oil), a common source of dietary fat in the developing world.

The fourteenth, fifteenth, and sixteenth columns (N, O, P) are the same as the tenth, eleventh, and twelfth (J, K, L) -- the productivity of the crop for each macronutrient -- except that the value is expressed as kg per hectare per crop, not per year. For a tree crop, the value is the same, because the crop season is essentially 12 months. For most crops, the value will be less. A crop that is three months should have a per crop value of one fourth of the per year value.

The seventeenth column (Q) is the productivity of the crop in kcal per square meter per crop, rather than per hectare. The kcal value is calculated in the same way as for the twelfth column, from the protein, fat, and carbohydrates content of the food.

ENDNOTES:

For the purposes of a practical evaluation of protein quality and essential amino acids, this article will use the following terms, based on a comparison between the Institute of Medicine's ideal values for essential amino acids and the content of each protein source:
*** A complete protein has all essential amino acids at or above 90% of IOM ideal.
** A near complete protein has all essential amino acids at or above 70% of IOM ideal.
* An incomplete protein is anything else.
For some of the more obscure crops, no reliable data on essential amino acid content was found.

Achira
Canna Edulis, a perennial that can be grown as an annual
The edible corms are rich in starch.

Nutrition data from: National Research Council, Lost Crops of the Incas: Little Known Plants of the Andes with Promise for Worldwide Cultivation, (New York: Books for Business International, 1989), p. 31: "Fresh tubers contain about 75 percent moisture. The dry matter contains 75–80 percent starch, 6–14 percent sugar (mostly glucose and sucrose), and 1-3 percent protein."
Calculation of whole food macronutrients from above dry matter data: 19.4% starch, 2.5% sugar, 21.9% carbs total, 0.5% protein.
Time to harvest and yield from: Lost Crops of the Incas, p. 33.
Fiber content from: Andrade-Mahecha, et al., "Physical–chemical, thermal, and functional properties of achira (Canna indica L.) flour and starch from different geographical origin"; http://onlinelibrary.wiley.com/doi/10.1002/star.201100149/abstract

Adzuki bean
Phaseolus angularis
Yield (3200 kg/ha) taken from the lowest yield of 4 varieties, in:
Hang, et al., "Plant Configuration and Population Effects on Yield of Azuki Bean in Washington State", 1993;
http://www.hort.purdue.edu/newcrop/proceedings1993/v2-588.html
Time to maturity (118 days) from:
Hardman, et al., "Adzuki Bean", Alternative Field Crops Manual;
http://www.hort.purdue.edu/newcrop/afcm/adzuki.html
USDA Nutrient data (SR24) used for "Beans, adzuki, mature seeds, raw"
Production quantity not reduced since reported weight is for clean dry beans.
** near complete protein; lysine 1.48, meth+cys 0.79, tryptophan 1.37

Almonds
Yield (1325 kg/ha) from FAOSTAT 2009 World data for Almonds, with shell.
USDA Nutrient data (SR24) used for "Nuts, almonds"
"Refuse: 60% (Shells)"
Production quantity reduced by 60% (to 40%).
* incomplete protein; lysine 0.54, meth+cys 0.64, tryptophan 1.44

Amaranth Grain
USDA Nutrient data (SR24) used for: "Amaranth, uncooked"
High and low yields (3 t/ha and 1 t/ha) from:
Myers, "Amaranth: New Crop Opportunity", 1996:
http://www.hort.purdue.edu/newcrop/proceedings1996/v3-207.html
Production quantity not reduced, since amaranth has no hulls to be removed (and yields are a rough estimate).
*** complete protein; lysine 1.01, meth+cys 1.15, tryptophan 1.79

Amaranth Leaf PC
Low yield (14 t/ha) from:
Edomwonyi, "Growth and Yield Performance of Amaranthus cruentus Influenced by Planting Density and Poultry Manure Application", 2008;
"The yield per hectare of this crop ... world average (14.27 t ha-1) (FAO, 2007)."
http://notulaebotanicae.ro/nbha/article/viewFile/3458/3176
High yield (30 t/ha) from:
Onyango, et al., "Feasibility of commercial production of amaranth leaf vegetable by small-scale farmers in Kenya"

African Crop Science Conference Proceedings, Vol. 9. pp. 767-772;
http://www.acsj.info/website/images/stories/PART%202/SOCIO-ECONOMICS/3.pdf
USDA Nutrient data (SR24) used for: "Amaranth leaves, raw"
"Refuse: 6% (Tough stems)"
Yield quantity reduced by 6%.
*** complete protein; lysine 1.01, meth+cys 1.06, tryptophan 1.80
Fiber from: Bokanga, "Processing of Cassava Leaves for Human Consumption", ISHS Acta Horticulturae 375: International Workshop on Cassava Safety, comparing macronutrient and fiber content of cassava to Amaranth leaves and other foods;
http://www.actahort.org/books/375/375_18.htm

Arracacha
Arracacia xanthorrhiza, Peruvian carrot
Yield (5 to 15 t/ha) and time to maturity (300 to 400 days) from:
Lost Crops of the Incas, p. 50-51.
Macronutrient data from:
International Potato Center, Pocket Guide to Nine Exotic Andean Roots and Tubers, Jose Luis Rueda, p. 10;
http://books.google.com/books?id=hqjjongiX9sC
Fiber content from: Garcia, et al., "Physicochemical and Functional Characterization of the Arracacha (Arracacia Xanthorriza) Flours for Instant Soups";
http://www.tandfonline.com/doi/abs/10.1080/11358120709487717

Arrowroot
Maranta arundinacea
Time to maturity from:
Jansen, et al., Food and Nutrition in Fiji: Food Production, Composition, and Intake, Volume one, (University of the South Pacific, 1990), p. 102.
Yield (2471 kg/ha) from:
International Starch Institute, "Arrowroot";
"An acre (0.4 hectares) of arrowroot yields about 6 tonnes of rhizomes, or fleshy roots, from which about 1 tonne of starch is obtained.... Florida arrowroot, which is poisonous until boiled, is prepared from a cycad."
http://www.starch.dk/isi/starch/arrowroot.asp
Calculation: 2.471 acres in a hectare times 1000 kg of starch (i.e. the starch rich flour) results in 2471 kg/ha.
USDA Nutrient data (SR24) used for: "Arrowroot, flour"
The entry for "Arrowroot, raw" has a protein level of 4.24%. The flour entry has detailed information on essential amino acids, but a much lower protein level. Arrowroot is mainly used as a carbohydrate staple in the flour form.
** near complete protein; lysine 0.85, meth+cys 1.60, tryptophan 1.90, but low total protein.
Arrowroot flour is an incomplete protein due to very low levels of total protein in the prepared flour. The root itself has about twice the total protein of potato, but processing into flour removes most of the protein.

Avocado fruit
USDA Nutrient data (SR24) used for: "Avocados, raw, all commercial varieties"
But avocados are too high in fiber at 5.6% to be a good protein staple. Possibly useful as an adjunct staple.

Avocados are 65% flesh, 15% skin, 20% stone, per:
Laurence Eyres, et al., Avocado Oil: A New Edible Oil from Australasia;
http://www.olivado.com/studies4.htm
Yield reduced to 65% for fruit.
*** complete protein; lysine 1.29, meth+cys 1.31, tryptophan 1.79

Avocado oil
A tree crop that bears fruit 4 to 5 years after planting, for up to 50 years.
Fruit yield (8852 kg/ha) from FAO 2009 World data
Percent oil extracted from fruit (cold pressed) is 13% per:
Laurence Eyres, et al., Avocado Oil: A New Edible Oil from Australasia;
"The season 2000-2001 saw approximately 1200 tonne of fruit processed yielding around 160 tonne of oil."
http://www.olivado.com/studies4.htm
The oil is high in monounsaturated fat, moderate in saturated fat, and low in omega-6, and very low in omega-3 fatty acids.

Bambara beans
A legume, also called "groundnut", like a bean with a peanut growth habit.
Macronutrient content per:
Onimawo, et al., "Proximate composition and functional properties of four cultivars of bambara groundnut (Voandezeia subterranea)"; http://www.springerlink.com/content/uv42006618648170/
and compared to:
Oluwole Steve Ijarotimi, Taiwo Ruth Esho, (2009) "Comparison of nutritional composition and anti-nutrient status of fermented, germinated and roasted bambara groundnut seeds (vigna subterranea)", British Food Journal, Vol. 111, Issue 4, pp. 376-386;
http://dx.doi.org/10.1108/00070700910951515
Other sources showed similar values.
Yield (805 kg/ha) from 2009 FAOSTAT World data.
Production quantity reduced by 23% (to 77%) due to mean shell percentage:
Mahama Ouedraogo et al., Characterization and evaluation of accessions of Bambara groundnut (Vigna subterranea (L.) Verdcourt) from Burkina Faso; Sciences & Nature Vol. 5 N°2 : 191 - 197 (2008); p. 194, table 1.
Time to maturity from:
J. Heller, et al., Proceedings of the workshop on Conservation and Improvement of Bambara Groundnut, 14–16 November 1995, Harare, Zimbabwe;
http://www.underutilized-species.org/documents/PUBLICATIONS/bambara_groundnut.pdf
no USDA Nutrient data (SR24)
lysine 1.34, meth+cys 1.24, according to:
Omoikhoje, S. O., "Assessment of the nutritive value of bambara groundnut as influenced by cooking time", Ambrose Alli University, Nigeria;
http://lrrd.cipav.org.co/lrrd20/4/omoi20055.htm
Essential amino acids from:
M.A.M. Mune, et. al., "Nutritional Potential of Bambara Bean Protein Concentrate", Pakistan Journal of Nutrition, 10 (2): 112-119, 2011;
Data used for "bambara flour", not the protein concentrate.
http://www.pjbs.org/pjnonline/fin1749.pdf
* incomplete protein; lysine 1.44, meth+cys 0.44, tryptophan 1.40.
All essential amino acids at or above 1.38, except meth+cys at 0.44.

This data from Mune conflicts with Omoikhoje above, but the one is flour and the other is whole beans.

Barley
USDA Nutrient data (SR24) data used for "Barley, hulled"
Production quantity reduced by 15% (to 85%) to account for hulls, per:
Thomason, et al., "Growing Hulless Barley in the Mid-Atlantic", Virginia Cooperative Extension, 2009;
"the hull makes up 12 percent to 15 percent of the weight of traditional barley"
http://pubs.ext.vt.edu/424/424-022/424-022.html
Yield data from FAOSTAT 2009 for United States (which is higher than the world average yield).
** near complete protein; lysine 0.73; meth+cys 1.65; tryptophan 2.38.

Beans broad
Vicia faba, a different genus than the common bean.
Yield from FOASTAT World data: 1,709 kg/ha
USDA Nutrient data (SR24) used for: "Broadbeans (fava beans), mature seeds, raw"
** near complete protein; lysine 1.25, meth+cys 0.84, tryptophan 1.35.

Beans cowpea
Vigna unguiculata subsp. unguiculata, blackeye pea
USDA Nutrient data (SR24) used for: "Cowpeas, common (blackeyes, crowder, southern), mature seeds, raw"
Yield (2000 kg/ha) estimated from: Davis, et al., Alternative Field Crops Manual, "Cowpea", average of four varieties, converted from lb/acre to kg/ha;
http://www.hort.purdue.edu/newcrop/afcm/cowpea.html
Time to maturity estimated from several varieties in 2011 SSE Yearbook.
*** complete protein; lysine 1.33, meth+cys 1.01, tryptophan 1.76.

Beans dry
Phaseolus spp. [spp. means 'various species']
shelled dried beans
USDA Nutrient data (SR24) data used for "Beans, pinto, mature seeds, raw"
Production quantity not reduced because yields are commonly stated after shelling, cleaning, and drying of beans.
"The United States produces many kinds of dry edible beans, but the leading varieties for 2006-08 were: Pinto, 42 percent; Navy (pea), 17 percent; Black, 11 percent; Great Northern, 5 percent; Garbanzo, (large chickpeas) 5 percent."
USDA ERS, Dry Beans; http://www.ers.usda.gov/Briefing/DryBeans/background.htm
Yield data from FAOSTAT 2009 for United States (which is higher than the world average yield).
** near complete protein; lysine 1.24; meth+cys 0.83; tryptophan 1.58.

Beans, green
genus: Phaseolus or Vigna, spp.
fresh shelled beans, not dried.
A separate category from "beans, dry" in FAO crop definitions and data.
Yield from FAOSTAT U.S. data: 3098 kg/ha. World data for yield does not make sense.
USDA Nutrient data (SR24) used for: "Lima beans, immature seeds, raw"

Nutrient data from Lima beans used because it is one of the most common immature (green) shelled beans.
** near complete protein; lysine 1.30, meth+cys 0.88, tryptophan 1.88.

Beans, mung
Vigna radiata
USDA Nutrient data (SR24) used for: "Mung beans, mature seeds, raw"
Yield (2000 lb/ac converted to 2240 kg/ha) and time to maturity from:
Oplinger, et al., "Mungbean", Alternative Field Crops Manual;
http://www.hort.purdue.edu/newcrop/afcm/mungbean.html
Time to maturity also from:
GardeningGuides.com, Frank Whittemore, "Life Cycle of the Mung Bean,"
http://www.gardenguides.com/98365-life-cycle-mung-bean.html
** near complete protein; lysine 1.37, meth+cys 0.83, tryptophan 1.56.

Beans, nuna
popping beans
A variety of the common bean, Phaseolus vulgaris, with thick skin, suitable for popping like corn (maize).
Time to maturity (148 days average) from:
Notes on Economic Plants, "Popping in Nuna Beans Grown Outside of Traditional Areas," 1990, p. 133.
http://www.jstor.org/discover/10.2307/4255220
Yield from FAOSTAT 2009 World data for "beans, dry"
USDA Nutrient data (SR24) data used for "Beans, pinto, mature seeds, raw"
** near complete protein, lacking only in methionine (assumed, since the species is the same as many other dry beans).
Fiber estimated from comparison with other dry beans.

Beans string
whole pod, not for shelling; also called snap beans.
USDA Nutrient data (SR24) data used for "Beans, snap, green, raw"
"Refuse: 12% (Ends, strings, trimmings)"
Production quantity reduced by 12% (to 88%).
Yield (13,450 kg/ha) from:
Oregon State University Commercial Vegetable Production Guide (converted to kg/ha)
http://nwrec.hort.oregonstate.edu/snapbean.html
** near complete protein; lysine 0.95, meth+cys 0.88, tryptophan 1.49.

Beans tepary
Phaeseolus acutifolius, also Phaeseolus filiformis
Time to maturity and protein content from:
Jay Bost, "Tepary Beans," Seeds of Change, eNewsletter, Issue 56;
A wild bean from the Sonoran desert in Mesoamerica: "considered by many to be the most drought-tolerant annual legume in the world.... It has a higher protein content (23–30%) than common beans such as pinto, kidney, and navy, as well as higher levels of oil, calcium, iron, magnesium, zinc, phosphorus, and potassium."
http://www.seedsofchange.com/enewsletter/issue_56/tepary_beans.aspx
Oil and carbohydrate content estimated from comparison with other beans.

Yield taken from beans, nuna; low estimate of yield due to limited development of this crop.
Fiber estimated from comparison with other dry beans.

Beans yardlong
Asparagus bean, Vigna unguiculata subsp. sesquipedalis, the same species as the cowpea
These beans are mainly used for their pods, as a type of long snap bean, rather than for the seeds alone.
Yield (1.6 kg/m2, 16000 kg/ha) from:
Ban, et al., "Influence of the Growing Method on Yield Components of Yard-long Bean", Agriculturae Conspectus Scientificus, Vol. 63, n. 4, 1998;
https://acs.agr.hr/acs/index.php/acs/article/view/371
USDA Nutrient data (SR24) used for: "Yardlong bean, raw" [which is the pods, not the seeds alone]
"Refuse: 5% Refuse Description: Ends"
*** complete protein; lysine 1.29, meth+cys 1.17, tryptophan 1.63.
Fiber estimated by multiplying the ratio of fiber to carbs in string beans ("Beans, snap, green, raw") times the carbs in yardlong beans.

Beechnuts
Not suitable as staple or adjunct staple food: trees do not bear substantial harvests until 50 years of age; even then, yields are highly variable; nuts are high in tannins and relatively low in protein.
Protein 6.2%; fat 50%; carbs 33.5%.
USDA Nutrient data (SR24) used for: "Nuts, beechnuts, dried"
"Refuse: 39% Refuse Description: Shells"
*** complete protein; lysine 1.16, meth+cys 2.21, tryptophan 1.59.

Brazil nuts
Most brazil nuts are still harvested from wild stands, so yield data is not available from the FAO.
The nuts are too high in selenium to be used as a staple or adjunct staple food.
According to the USDA Nutrition database (SR24), 6 brazil nuts per day provides 543.5 micrograms of selenium. The tolerable upper limit for selenium is 400 micrograms per day for adults, and less for teens and children, according to the National Institutes of Health.
http://ndb.nal.usda.gov/ndb/foods/show/3703
http://ods.od.nih.gov/factsheets/Selenium-HealthProfessional/#h7

Breadfruit fruit
USDA Nutrient data (SR24) used for: "Breadfruit, raw"
"Refuse: 22% Refuse Description: 9% core, 13% skin"
Breadfruit is a poor source of protein, at 1.07% protein by weight; 4% by calories.
* incomplete protein; lysine 0.68, meth+cys 0.71, phenylalanine+tyrosine 0.89;
some essential amino acids not tested or not found.

Breadfruit seeds
Perfect balance of macronutrients; near perfect balance of dietary fat;
per 100 grams of food:
kcal: 191
protein: 7.40 g (16.5% of calories)
fat: 5.59 g (25.9% of calories)
omega-6 -- 2.290 (41% of the fat)
omega-3 -- 0.687 (12.3% of the fat)

omega-6 to omega-3 ratio: 3.33 to 1
carbs: 29.24 g (59.2% of calories)
Yield from:
National Tropical Botanical Garden, Breadfruit Institute, "Tree to Table," Yields;
"Mature breadnut trees in the Philippines were reported to produce 600-800 fruit per season, but 200 fruit per tree is a more realistic figure. Each fruit weighs 800 g on average with seeds comprising 30-50% or more of the total fruit weight. The average number of seeds per fruit is variable, ranging from 15 to 98, each seed weighing an average 9 g. A hectare planted with 100 trees, each averaging 200 fruit/tree will yield 11 metric tons of fresh seeds."
http://ntbg.org/breadfruit/uses/table1.php
USDA Nutrient data (SR24) used for: "Seeds, breadfruit seeds, raw"
"Refuse: 32% Refuse Description: Shells"
*** complete protein; lysine 1.51, meth+cys 1.15, tryptophan 2.37.

Broccoflower
Also called "green cauliflower"
A cross between broccoli and cauliflower, having the higher protein of broccoli and the better essential amino acid profile of cauliflower. Note that not all green-colored cauliflowers are the result of such a cross. Romanesco broccoli or Roman cauliflower is similar to Broccoflower (a trademarked name), except that the phenotype exhibits a fractal pattern in the flower buds.
Yield (21,353 kg/ha) from FAOSTAT 2009 USA data for "Cauliflowers and broccoli"
FAOMETA data: "Brassica oleracea var. botrytis, subvariety cauliflora and cymosa. Includes headed broccoli."
USDA Nutrient data (SR24) used for: "Cauliflower, green, raw"
"Refuse: 39% (Leaf stalks, core and trimmings)"
Yield reduced by 39% (to 61%); but for the PC listing of the crop, not reduction in yield was needed since the whole head and outer leaves can be used to make protein concentrate.
Time to harvest for the set of all cauliflowers is very variable.
*** complete protein; lysine 1.05, meth+cys 1.03, tryptophan 1.89.
Broccoflower has a higher percent protein (2.95%) than cauliflower (1.98%).

Broccoli
Yield from FAOSTAT 2009 USA data: 20,812 kg/ha
USDA Nutrient data (SR24) used for: "Broccoli, raw"
"Refuse: 39% (Leaves and tough stalks with trimmings)"
Yield quantity reduced by 39% (to 61%).
Oregon State University, "Broccoli", Commercial Vegetable Production Guides;
"Yields of processing broccoli average approximately 5.5 tons/acre with good yields at 7.5 tons."
These yields convert to: 12,329 to 16,812 kg/ha.
http://nwrec.hort.oregonstate.edu/broc-pr.html
** near complete protein; lysine 0.94, meth+cys 0.94, tryptophan 1.67, leucine 0.83

Broccoli PC
Preparation of a protein concentrate from broccoli assumes less refuse; most of the tough stalks, leaves, and trimmings can be used. The stalks, florets, and leaves all have about the same nutritional content, per USDA SR24.
Yields of broccoli and cauliflower are lower than for broccoli raab or kale because, for the former, the grower is concerned with the size, shape, color of the product. Excess leaves and stems are trimmed away in the former, not in the latter.

Broccoli Raab PC
USDA Nutrient data (SR24) used for: "Broccoli raab, raw"
Yield quantity reduced by 10% (to 90%).
Yield average (35.5 t/ha) from two cultivars:
Calabrese, et al., "Suitability to Freezing of Two Broccoli Raab (Brassica Rapa L.) Cultivars", Acta Hort. (ISHS) 407:313-320;
"Total yield was 32 and 39 t/ha respectively" for two different cultivars.
http://www.actahort.org/books/407/407_39.htm
*** complete protein; lysine 1.22, meth+cys 1.10, tryptophan 1.94, Leucine 0.98.

Buckwheat
USDA Nutrient data (SR24) used for "Buckwheat"
Production quantity reduced by 25% to account for hulls, per:
Robert L. Myers and Louis J. Meinke, Department of Agronomy, University of Missouri Extension, 'Buckwheat: A Multi-Purpose, Short-Season Alternative';
http://extension.missouri.edu/publications/DisplayPub.aspx?P=G4306
Yield (1093 kg/ha) from FAOSTAT 2009 for United States.
*** complete protein; lysine 0.99, meth+cys 1.21, tryptophan 2.07.

Cabbage savoy low yield
Yield (28131 kg/ha) from FAOSTAT world data 2009 for "Cabbages and other brassicas"
FAO Metadata: "Chinese, mustard cabbage, pak-choi (Brassica chinensis); white, red, savoy cabbage, Brussels sprouts, collards, kale and kohlrabi (Brassica oleracea all var. except botrytis [cauliflower])."
USDA Nutrient data (SR24) used for: "Cabbage, savoy, raw"
"Refuse: 20% (Outer leaves and core)"
Yield quantity reduced by 20% (to 80%).
** near complete protein; lysine 0.92, meth+cys 0.74, tryptophan 1.43, Leucine 0.94.
The Savoy variety has the better essential amino acid profile compared to other cabbages (green, red, Chinese).

Cabbage savoy high yield
Yield of 70 metric tonnes/ha (700 metric quintal) from:
"New Sungro Cabbage varieties"
http://www.indiaagronet.com/indiaagronet/Technology_Upd/contents/NewSungroCabbagevarieties.htm

Cabbage, pak-choi PC
Yield and time to maturity estimated from:
Wanitprapha, et al., "Won Bok & Pak Choi", Economic Fact Sheet, Department of Agricultural and Resource Economics College of Tropical Agriculture and Human Resources University of Hawaii;
http://www.ctahr.hawaii.edu/sustainag/extn_pub/veggie%20pubs/Oriental%20Vegetables/Won%20Bok%20and%20Pak%20Choi.pdf
USDA Nutrient data (SR24) used for "Cabbage, chinese (pak-choi), raw"
"Refuse: 12% Refuse Description: Base and damaged leaves"
Production quantity not reduced since the whole plant is used for protein concentrate
* incomplete protein; lysine 1.07, meth+cys 0.69, tryptophan 1.43

Camelina sativa
An oil seed, related to broccoli, that has high oxidative stability, despite a high proportion of omega-3 fatty acid. The unrefined oil will keep for 2 years without refrigeration. One of the few oils that does not need refinement to be palatable.
Time to maturity (70 to 90 days) from:
Hancock Seed Company, "Camelina Seed,"
"Camelina has a wide range of adaptability, fitting into many different cropping systems due to its short period of growth (70–90 days)."
http://www.hancockseed.com/camelina-bio-fuel-seed-546/camelina-seed-547/camelina-seed-50-lb-bag-506.html
Yield of 1,000 to 2,000 lb/acre (converted to 1120 and 2240 kg/ha) estimated from several sources, including:
Ehrensing and Guy, "Camelina", Oilseed Crops, January 2008;
"Under dryland conditions in Montana, camelina is expected to yield 1,800 to 2,000 pounds of seed per acre in areas with 16 to 18 inches of rainfall, and 900 to 1,700 lb/acre with 13 to 15 inches of rainfall. Under irrigation, seed yields of 2,400 lb/acre have been reported. Three years of yield trials at Moscow, Idaho show a 2,000 to 2,400 lb/acre seen yield potential with 25 inches of rainfall."
http://extension.oregonstate.edu/catalog/pdf/em/em8953-e.pdf
Nutritional content estimated from several sources, including:
Putnam, et al., "Camelina: A Promising Low-Input Oilseed", UTILIZATION - Seed Composition, Oil Content and Meal Quality, In Janick and Simon (eds.), New crops (Wiley, New York: 1993), p. 314-322.
http://www.hort.purdue.edu/newcrop/proceedings1993/V2-314.html
Camelina meal (press cake) essential amino acids profile from:
J. Zubr, "Dietary Fatty Acids and Amino Acids of Camelina Sativa Seed", Journal of Food Quality, 2007;
http://onlinelibrary.wiley.com/doi/10.1111/j.1745-4557.2003.tb00260.x/abstract
Tryptophan content estimated from:
Frame, et al., "Feeding Camelina Sativa and Enhancing Omega-3 Fatty Acid Levels in Market-age Turkey Hens", AG/Poultry, 2008-01;
http://extension.usu.edu/files/publications/publication/AG_Poultry_2008-01.pdf
*** complete protein; lysine 0.97, meth+cys 1.54, tryptophan 1.21.
Camelina meal and camelina whole seed are each complete proteins. Fiber content from: Plessers, et al., "Species Trials with Oilseed Plants: II. Camelina", Canadian Journal of Plant Science;
http://pubs.aic.ca/doi/abs/10.4141/cjps62-073

Carrots
USDA Nutrient data (SR24) used for: "Carrots, raw"
"Refuse: 11% (Crown, tops and scrapings)"
Yield quantity reduced by 11% (to 89%).
Low yield from FAOSTAT "Carrots and turnips"
FAOMETA data: "Daucus carota. Trade data may include turnips (Brassica rapa var. rapifera)."
High yield from U.S. Carrot Statistics, Table03-1.xls, processing carrots, 2000 to 2009 (tons/ac converted to kg/ha)
http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1577
*** complete protein; mature carrots (not baby carrots) are low in total protein, but otherwise they have an excellent protein profile, with all essential amino acids in more than ideal percentages, including: lysine 2.13, meth+cys 4.43, tryptophan 1.84.

The high yields and excellent essential amino acid profile suggest that carrots would be a good source of protein concentrate (PC).

Cashew nuts
Yield from 2009 FAOSTAT world data: 799 kg/ha.
Optimum yield of 3100 kg/ha from:
J.H.G. Waithaka, "Kenya - Assessment of the Situation and Development Prospects for the Cashew Nut Sector", July 2002, p. 15;
www.unctad.org/infocomm/francais/anacarde/Doc/kenya.pdf
Production quantity reduced by 75% (to 25%), per:
Gayathri Industries, 'Cashew Nut Processing An Overview';
"A pair of skilled worker normally de-shells about 80 kg of cashew nuts in 8 hrs, which yields approximately 20 kg of Cashew kernel."
http://www.cashewmachines.com/Documents/CASHEWNUT PROCESSING AN OVERVIEW.pdf
USDA Nutrient data (SR24) used for: "Nuts, cashew nuts, raw"
*** complete protein; lysine 1.00, meth+cys 1.66, tryptophan 2.25.

Cassava
USDA Nutrient data (SR24) used for "Cassava, raw"
Production quantity reduced by 10% to account for peelings, per:
Adegbola and Asaolu, "Preparation of cassava peels for use in small ruminant production in western Nigeria", Department of Animal Science, University of Ife, Ile-Ife, Nigeria;
http://www.fao.org/wairdocs/ilri/x5487e/x5487e0g.htm
Time to harvest (8 to 14 mo.) from:
O'Hair, "Tropical Root and Tuber Crops", in Advances in New Crops, Janick and Simon, eds., (Portland, Oregon: Timber Press, 1990), p. 424-428;
http://www.hort.purdue.edu/newcrop/proceedings1990/V1-424.html#Cassava
* incomplete protein; cassava is a very poor source of protein, with very low total protein and less than ideal percentages of ALL essential amino acids, EXCEPT tryptophan, meth+cys, and arginine.

Cauliflower
Yield from FAOSTAT 2009 USA data: 20,812 kg/ha
USDA Nutrient data (SR24) used for "Cauliflower, raw"
"Refuse: 61% Refuse Description: Leaf stalks, cores and trimmings"
Production quantity reduced by 61% (to 39%).
*** complete protein; lysine 1.05, meth+cys 1.03, tryptophan 1.88.

Chestnuts
Yield from FAOSTAT 2009 World data: 3673 kg/ha
USDA Nutrient data (SR24) used for "Nuts, chestnuts, european, raw, unpeeled"
"Refuse: 26% Refuse Description: Shells"
Yield reduced by 26% (to 74%)
*** complete protein; lysine 1.16, meth+cys 2.21, tryptophan 1.59.
Low in total protein: 2.42%.

Chia seed
USDA Nutrient data (SR24) used for: "Seeds, chia seeds, dried" (Salvia hispanica)
Yield and time to harvest data from:

Jamboonsri, "Improvement of New Oil Crops for Kentucky", University of Kentucky, 2010;
"Commercial chia seed yields are generally 500-600 kilograms per hectare (Coates and Ayerza, 1996), however some growers have obtained up to 1,260 kg/ha. Some experimental plots yielded 2,500 kg/ha when irrigation and nitrogen fertilizer were applied." (p. 7).
"The crop cycle varies from 90 to 150 days depending on the latitude where it is planted." (p. 6).
http://uknowledge.uky.edu/gradschool_diss/120
*** complete protein; lysine 1.15, meth+cys 1.15, tryptophan 3.77 (my calculations from SR24 data).
Chia seeds are an excellent source of tryptophan.

Chickpeas
garbanzo beans, bengal gram
USDA Nutrient data (SR24) used for: "Chickpeas (garbanzo beans, bengal gram), mature seeds, raw"
Yield from FAOSTAT 2009 USA data
*** complete protein; lysine 1.31, meth+cys 1.06, tryptophan 1.37.

Chufa (tigernut)
cyperus esculentus
Daisy E. Kay, revised by E. G. B. Gooding, Root Crops, 2nd edition, (London: Tropical Development and Research Institute, 1987)
"in Spain, with large-scale cultivation, yields as high as 8,000 - 14,000 kg/ha are reported."
Greenstone.org, Food and Nutrition Library 2.2
http://www.greenstone.org/greenstone3/nzdl
Yields in the developing world and time to harvest, from:
JP Tetteh, E Ofori, "A baseline survey of tiger nut (Cyperus esculentus) production in the Kwahu South District of Ghana", School of Agriculture, University of Cape Coast.
Even without fertilizer, one third of the farmers obtain yields in the range of 9 to 11.3 kg/ha. The other farmers used a lower seeding rate, and obtained correspondingly lower yields.
http://www.ajol.info/index.php/gjas/article/viewFile/1934/10753
Nutrient data, including fiber, from:
Arafat, et al., "Chufa Tubers (Cyperus esculentus L.): As a New Source of Food", 2009, World Applied Sciences Journal 7 (2): 151-156; http://www.idosi.org/wasj/wasj7(2)/4.pdf
Time to harvest from: Cyprus Knee Chufa, FAQ; http://www.cyprusknеechufa.com/faqs.html
** near complete protein
Chufa possibly has less than ideal percentages of leucine and/or lysine. Several sources of information were consulted, and none were in agreement. Essential amino acid content may vary based on variety of chufa and other factors. By all accounts chufa is at least a near compete protein.

Coconut meat
Whole coconut is 30% meat, so yield is reduced by 70% (to 30%).
USDA Nutrient data (SR24) used for: "Nuts, coconut meat, raw"
Essential amino acids analysis from BitterPoison.com
http://www.bitterpoison.com/protein/12104/
** near complete protein; lysine 0.87, meth+cys 1.54, tryptophan 1.67

Coconut oil
from copra (dried coconut meat) or fresh coconuts
Low yield data from FAOSTAT 2009 World average:

5201 kg of coconuts (fresh, whole) per hectare.
High yield estimate and macronutrient data:
Julian A. Banzon, "The Coconut as a Renewable Energy Source", Philippine Journal of Coconut Studies, June 1980;
Fig. 1. Relative Amounts of Components of an Average Coconut (data from the United Coconut Association of the Philippines - UCAP);
Whole Coconut: Meat 30%; Shell 15%; Husk 33.3%; Coco water 21.7%; Oil 10% of whole coconut, or 33.33% of meat.
http://www.pcrdf.org/artimages%5Cart%203.doc
Calculated yield of oil from whole coconut, using above data: 520.1 kg/ha of oil.
Calculated high yield of whole coconuts from average weight (1.2 kg) and average nuts per ha per year (10,000) per Banzon, cited above.

Collard greens PC
Crop analyzed here for use as protein concentrate (PC), not as a vegetable.
USDA Nutrient data (SR24) used for: "Collards, raw"
"Refuse: 43% (Stems)"
Yield not reduced because stems can be used in PC.
Yield (9.0 to 14.5 t/ha) from:
Dangler and Wood, "Nitrogen Rate, Cultivar, and Within-row Spacing Affect Collard Yield and Leaf Nutrient Concentration", Hortscience 28(7):701-703. 1993;
http://hortsci.ashspublications.org/content/28/7/701.full.pdf
Time to harvest (3 to 4 mo.) from:
Seed Savers Exchange Yearbook 2011
*** complete protein; lysine 0.94, meth+cys 0.95, tryptophan 1.81

Cottonseed oil
Oil yield (400 kg/ha) estimated based on:
Sawana, et al., "Cottonseed: protein, oil yields, and oil properties as influenced by potassium fertilization and foliar application of zinc and phosphorus", Cotton Research Institute, Egypt, 2007;
http://grasasyaceites.revistas.csic.es/index.php/grasasyaceites/article/download/7/7
Days to maturity estimated from comparison of multiple sources.

Cowpea
Vigna unguiculata subsp. unguiculata, blackeye pea, a type of bean
USDA Nutrient data (SR24) used for: "Cowpeas, common (blackeyes, crowder, southern), mature seeds, raw"
Yield (2000 kg/ha) estimated from: Davis, et al., Alternative Field Crops Manual, "Cowpea", average of four varieties, converted from lb/acre to kg/ha;
http://www.hort.purdue.edu/newcrop/afcm/cowpea.html
Time to maturity estimated from several varieties in 2011 SSE Yearbook.
*** complete protein; lysine 1.33, meth+cys 1.01, tryptophan 1.76.

Cucumbers
Yield (15,819 kg/ha) from FAOSTAT 2009 data for United States.
Time to maturity (2.5 months) estimated from 2011 SeedSavers Yearbook.
USDA Nutrient data (SR24) used for "Cucumber, with peel, raw"
"Refuse: 3% Refuse Description: Ends"
Production quantity reduced by 3%.

* incomplete protein; lysine 0.87, meth+cys 0.62, tryptophan 1.10, leucine 0.81

Daikon
Raphanus sativus var. longipinnatus, oriental radish
High yield (139 t/ha) as average of 4 best cultivars, December Harvest: 79 days, in:
Morgan and Midmore, "Daikon in Australia", Australian Government Rural Industries Research and Development Corporation;
Table 4: Best performing daikon cultivars at Medina, Western Australia 1998-1999;
https://rirdc.infoservices.com.au/downloads/03-091.pdf
Moderate yield from above source, same table, which shows 7 varieties with an average yield of over 100 MT, each with time to harvest of 92 days or less.
USDA Nutrient data (SR24) used for "Radishes, oriental, raw"
"Refuse: 21% Refuse Description: Tops and parings"
Production quantity reduced by 21% for listing: "daikon moderate yield".
Production quantity not reduced for listing: "daikon PC high," since a Protein Concentrate made from daikon would use tops and pairings.
** near complete protein; lysine 0.98, meth+cys 0.73, tryptophan 0.71, leucine 0.94

Duckweed
Yield source data is kg/ha-yr of dry matter (DM)
Yield and nutritional content are conservative estimates based on: Leng, et al., "Duckweed - a potential high-protein feed resource for domestic animals and fish", 1995;
http://www.fao.org/ag/aga/agap/frg/LRRD/LRRD7/1/3.HTM
and: John Cross, The Charms of Duckweed, 'Duckweed nutritional composition' (updated 2003);
http://www.mobot.org/jwcross/duckweed/nutritional-composition.htm
and: Rusoff, et al., "Duckweeds (Lemnaceae family): a potential source of protein and amino acids", Journal of Agricultural and Food Chemistry, 1980;
http://pubs.acs.org/doi/abs/10.1021/jf60230a040
* incomplete protein; lysine is 0.89, methionine and valine are particularly low (per Rusoff et al).
Fiber, average of the range of values (5.7 to 16.2) in: John Cross, The Charms of Duckweed, 'Duckweed nutritional composition' (updated 2003);
http://www.mobot.org/jwcross/duckweed/nutritional-composition.htm

Eggplant
Yield (16.5 tons per acre converted to 3.7 metric tonnes per hectare) estimated from:
Aguiar, et al., "Eggplant Production in California", 1995;
http://anrcatalog.ucdavis.edu/pdf/7235.pdf
Time to maturity estimated from 2011 SeedSaver's Exchange Yearbook.
USDA Nutrient data (SR24) used for "Eggplant, raw"
"Refuse: 19% Refuse Description: Ends, parings and trimmings"
Production quantity reduced by 19% (to 81%)
* incomplete protein; lysine 0.91, meth+cys 0.67, tryptophan 1.27

Egusi seeds
Seeds from various curcurbits:
Nutrient data used for "Cucumis sativus" in: Achu, et al., "Nutritive value of some Cucurbitaceae oilseeds from different regions in Cameroon", African Journal of Biotechnology Vol. 4 (11), pp. 1329-1334, November 2005, Table 1;
http://www.ajol.info/index.php/ajb/article/viewFile/71373/60323

Yield estimated from: Ayodele, "Phosphorus Fertilizer use in Melon (Egusi) Seed Production: Effects on Yield, Oil and Protein Content and Nutrient Composition," Agric. J., 1 (4): 216-220, 2006, p. 217; http://www.medwelljournals.com/abstract/?doi=aj.2006.216.220
** near complete protein; high in methionine and tryptophan, limiting amino acids are lysine and threonine, per: National Research Council, Lost Crops of Africa, Volume II, Vegetables, (Washington, D.C.: National Academy of Sciences, 2006), p. 162.

Enset
Ensete ventricosum
Macronutrient data, protein 4.42%, fat 0.24%, carbs 76.34%, fiber 7.14%, taken as an average of six varieties from: Tsehaye and Kebebew, "Diversity and cultural use of Enset (Enset ventricosum (Welw.) Cheesman) in Bonga in situ Conservation Site, Ethiopia.", p. 150; http://scholarspace.manoa.hawaii.edu/bitstream/handle/10125/246/I1547-3465-04-147.pdf
Yield of 95 qt/ha (=9500 kg/ha) from: Ali B. Dinar, "Enset: Background and Literature Reviewed", citing: Pijls, Loek, Arnold Timmer, Zedew W/Gebriel, and Clive West. 1994. Cultivation, preparation and consumption of Enset in Ethiopia. J Sci Food Agric. July 16; "Pijls et al, in a study of 60 households in Gurage Zone, found an average family size of 6.1 consumed 46 plants per year each yielding 34 kg/plant for an estimated production of 95 qt/ha."
"Enset is a flexible-harvest crop in that households have the option to utilize it at any time after maturity - i.e. a mature Enset plant becomes a mini household food security system available for harvesting and processing immediately or it can be `held in reserve' for another 5 to 10 years and it continues to grow and mature."; http://www.africa.upenn.edu/EUE/enset.html

Flaxseed
Yield (1492 kg/ha) from FAOSTAT 2009 for Canada, one of the top-producing nations for flaxseed.
USDA Nutrient data (SR24) data used for "Seeds, flaxseed"
*** flaxseed is a complete protein; lysine 0.92, meth+cys 1.55, tryptophan 2.32.

Fonio
Yield (2 t/ha) estimated from: Clottey, et al., "The potential of fonio (Digitaria exilis, Stapf) as feed for monogastrics", Savanna Agricultural Research Institute, 2006; "Grain yield of the fonio genotypes obtained ranged from 1.9 to 2.4 t ha-1 [metric tonnes per hectare].";
http://www.lrrd.org/lrrd18/7/clot18095.htm
Essential amino acids and macronutrients from: Protabase Record display, "Digitaria exilis (Kippist) Stapf":
"The composition of whole fonio grain per 100 g edible portion is: water 11.2 g, energy 1390 kJ (332 kcal), protein 7.1 g, fat 3.0 g, carbohydrate 74.4 g, fibre 7.4 g, Ca 41 mg, P 191 mg, Fe 8.5 mg, thiamin 0.24 mg, riboflavin 0.10 mg and niacin 1.9 mg (Leung, Busson & Jardin, 1968). The essential amino-acid content per 100 g grain is: tryptophan 111 mg, lysine 205 mg, methionine 441 mg, phenylalanine 402 mg, threonine 315 mg, valine 457 mg, leucine 772 mg and isoleucine 315 mg (FAO, 1970). The amino acid composition of fonio is comparable with that of other cereals, but it has a relatively high methionine content. The palatability of fonio grain is considered high."
http://database.prota.org/dbtw-wpd/exec/dbtwpub.dll?ac=qbe_query&bu=
http://database.prota.org/search.htm&tn=protab~1&qb0=and&qf0=Species+Code&qi0=Digitaria+exilis&rf=Webdisplay
Production quantity reduced by 23% (to 77%) per: CIRAD, La Recherché Agronomique pour le Developpement, "Fonio, Processing Diagram";
http://fonio.cirad.fr/en/the_grain/processing_diagram
* incomplete protein; lysine 0.64, meth+cys 2.82, tryptophan 2.61

Fonio is probably an incomplete protein, due to a low percent of lysine. However, data is sparse and nutritional content may vary substantially in different cultivars. Fonio appears to be much higher in methionine and tryptophan than other grains.

Hazelnuts
also Filberts
USDA Nutrient data (SR24) used for "Nuts, hazelnuts or filberts"
Yield from FAOSTAT 2009 World data for hazelnuts with shell: 1,273 kg/ha.
Percent of kernel varies, with an average of around 33% kernel to whole nut with shell, per:
Scott J. Josiah, "Commercial Hazelnuts in Minnesota", University of Minnesota Extension, WW-07280, 2009;
"Percent kernel, a more accurate gage of commercial production potential, varies from 25-40 percent (averaging around 30-37 percent for Badgersett's higher producing varieties), which is lower than commercial C. avellana varieties."
http://www.extension.umn.edu/distribution/naturalresources/dd7280.html
* incomplete protein; lysine 0.55, meth+cys 1.33, tryptophan 1.84.

Hempseed
Time to harvest from:
Finola.com, "Some things you should know about FINOLA", 25 February 2011;
http://www.finola.com/Finola_basic_info_280211.pdf
Yield data (farm average versus small plot manual) from:
Vogl, et al., "Comparing Hemp Seed Yields (Cannabis sativa L.) of an On-Farm Scientific Field Experiment to an On-Farm Agronomic Evaluation Under Organic Growing Conditions in Lower Austria", Journal of Industrial Hemp, Vol. 9(1) 2004;
Yield reduced by 30% (to 70%) per:
"the final weight of seeds to be sold fell, on average, 30% below the reported yield after the combine harvest"
http://orgprints.org/6928/
Macronutrient data from:
Hemp Oil Canada Inc., "Hemp Food Nutrition";
http://www.hempoilcan.com/nutrition.php
and
Finola.com, "Description of FINOLA oilseed nutrition";
http://www.finola.com/nutrition.html
Essential amino acids analysis from:
http://www.ergo-log.com/hempprotein.html
which cites: J Agric Food Chem. 2010 Nov 24;58(22):11801-7;
http://www.ncbi.nlm.nih.gov/pubmed/20977230
and
Finola.com, "Description of FINOLA oilseed nutrition",
http://www.finola.com/nutrition.html
** near complete protein; lysine 0.82, meth+cys 1.62, tryptophan 1.16.
Whole hemp seed is a near complete protein, except for lysine (Finola.com) 0.82 of ideal (1.00) according to Finola.com, using IOM standard. And "J Agric Food Chem. 2010" reports that lysine is first limiting amino acid, but gives it a lower score despite using FAO/WHO standards, which have lower ideal for lysine content.
Fiber content estimated from: Hempseed.ca, "Hulled Hemp Seed Hearts", 3.9 g fiber per 6.7 g carbs, applied to 30% carb content.

Indian bread-root
Psoralea esculenta pursh
aka Indian turnip
Kaufman, Natural Products from Plants, (CRC Press, 1999), p. 139;
total protein 7%
http://books.google.com/books?hl=en&id=lRiXOB5w9xEC
* incomplete protein; lysine 0.77; meth+cys 0.60, tryptophan 1.29, threonine 0.78, isoleucine 0.75, leucine 0.64, valine 0.77, tyrosine 0.95

Jerusalem artichoke
Yield of 20,000 kg/ha average from:
Cosgrove, et al., Alternative Field Crops Manual, "Jerusalem Artichoke", 1991;
"Most cultivars require a growing season of at least 125 frost-free days."
http://www.hort.purdue.edu/newcrop/afcm/jerusart.html
USDA Nutrient data (SR24) used for: "Jerusalem artichokes, raw"
"Refuse: 31% Refuse Description: Parings"
Yield reduced by 31% to 69%.
** near complete protein: lysine 0.88, Leucine 0.73, Methionine 0.92, Tyrosine 0.93

Job's tears
Coix lacryma Jobi
Nutrient data, time to harvest (4-6 mo.), and yield (2-4 t/ha husked) from:
G. Belay, Cereals and pulses, p. 47
hulled grain: 11.6 g water, 14.8 g protein, 4.9 g fat, 66.9 g carbs,
deficient in tryptophan 0.71 and lysine 0.37; methionine 1.04
http://books.google.com/books?id=dH6S9MwTupUC
Additional yield and nutritional information from:
James A. Duke, Handbook of Energy Crops, 1983;
http://www.hort.purdue.edu/newcrop/duke_energy/Coix_lacryma-jobi.html
Fiber content from: Woo, et al., "Comparative studies on the dietary fiber, amino acids and lipid components of Yullmoo and Yeomjoo"; http://agris.fao.org/agris-search/search/display.do?f=1990/KR/KR90012.xml;KR9035176
* incomplete protein: lysine 0.37, Methionine 1.04, tryptophan 0.71.

Kale
but not scotch kale, which has a lower percent protein
Total protein: Kale: 3.3%, Scotch kale: 2.8%
Yield of 10 metric tonnes of dry matter per hectare from:
Specialty Seeds NZ Ltd., "Brassica Winter Sowing Options";
Each of 10 different cultivars of kale had over 10 t/ha DM with a 5 to 7 month growing season;
http://www.specseed.co.nz/brassicawinter.asp
Converted from DM to whole food based on water content of "Kale, raw" in SR24 of 84.5%, resulting in 65.5 t/ha of kale including the water.
Average growing season of 6 months used for calculation of macronutrient productivity.
USDA Nutrient data (SR24) used for: "Kale, raw"
"Refuse: 39% (Stem ends, tough stems and tough midrib parts)"
Yield quantity reduced by 39% (to 61%).
*** complete protein; lysine 1.17, meth+cys 0.92, tryptophan 1.73.

Kaniwa
cañihua, chenopodium pallidicaule, a species of goosefoot related to quinoa
Macronutrient data from:
Ritva Repo-Carrasco-Valencia, et al., "Chemical and Functional Characterization of Kañiwa (Chenopodium pallidicaule) Grain, Extrudate and Bran", Plant Foods for Human Nutrition, Vol. 64, n. 2 (2009), 94-101;
http://www.springerlink.com/content/r687263w16457842/
*** complete protein; lysine 1.04, meth+cys 1.84, tryptophan 1.29.
Essential amino acid data from Repo-Carrasco 1992.
Fiber content from: Diaz, "Use of Amaranth, Quinoa and Kañiwa in Extruded Corn Snacks", 2012;
https://helda.helsinki.fi/handle/10138/32527

Kohlrabi PC
Yield (15,700 kg/ha) from:
Oregon State University, Commercial Vegetable Production Guides, "Kohlrabi", 2002;
"Kohlrabi yield is approximately 120-160 cwt/acre."
http://nwrec.hort.oregonstate.edu/kohlrabi.html
USDA Nutrient data (SR24) used for "Kohlrabi, raw"
Refuse: 54% Refuse Description: Leaves, stems and parings
Production quantity not reduced since this analysis considers protein concentrate from Kohlrabi
* incomplete protein; lysine 0.65, meth+cys 0.47, tryptophan 0.84, leucine 0.72, phenylalaine 0.49 (calculated from SR24)

Leeks
Leek yield (41471 kg/ha) from Oregon State University Commercial Vegetable Production Guide (and converted to kg/ha)
http://nwrec.hort.oregonstate.edu/leek.html
USDA Nutrient data (SR24) used for: "Leeks, (bulb and lower leaf-portion), raw"
"Refuse: 56% (Tops, root end and skin)"
Yield quantity reduced by 56% (to 44%).
But for Leeks PC, quantity only reduced by 20%, since protein concentrate allows more of the plant to be used for food.
*** complete protein; lysine 1.02, meth+cys 1.15, tryptophan 1.14.

Lentils
Yield from FAOSTAT 2009 U.S. data: 1614 kg/ha.
Milling efficiency from:
J. L. Bruce, "The effects of preharvest treatments on the milling efficiency of red lentil", 2008;
"Early desiccation significantly reduced milling efficiency to below 70%, whereas early swathing resulted in milling efficiency above 85%."
http://library2.usask.ca/theses/available/etd-12192008-095234/
USDA Nutrient data (SR24) used for: "Lentils, raw"
Essential amino acids data from BitterPoison.com for "Lentils, pink, raw"
** near complete protein; lysine 1.37, meth+cys 0.86, tryptophan 1.28.

Lettuce green leaf PC
Evaluated here for possible use in protein concentrate (PC)
Some varieties are ready in 60 days or less; others closer to 80 days.

USDA Nutrient data (SR24) used for: "Lettuce, green leaf, raw"
Yield from FAOSTAT 2009 USA data
*** complete protein; lysine 1.21, meth+cys 0.94, tryptophan 0.95.

Maca
Lepidium meyenii, a root
High and low yields from:
National Research Council, Lost Crops of the Incas, 1989, p. 62.
Macronutrient data from: Joachim Heller, "Andean roots and tubers: ahipa, arracacha, maca and yacon," International Plant Genetic Resources Institute, 1997, p. 186;
http://books.google.com/books?id=j7pgT1lDoggC
And: Flores, et al., "Andean Root and Tuber Crops: Underground Rainbows", 2003;
http://lamar.colostate.edu/~jvivanco/papers/Hort%20Science/2003.pdf
Dry weight macronutrient data: protein 10.2 g, fat 2.2 g, carbs 59.0 g, fiber 8.5 g per 100 gram dry food.
Adjusted to whole food data: protein 2.04%, fat 0.44%, carbs 11.8%, fiber 1.7%
Time to harvest from: Lost Crops of the Incas, p. 61; Harvest in as little as 6 months, and as long as 9 months, but crop is grown in cold, dry, high altitude regions; not rotated with any other crop, so 12 months is used as the growing season.
Yields reduced by 80% to 20%, since macronutrient data is for the dried crop; fresh maca is 80% water.
Essential amino acids analysis from: Antonio Bianchi, "MACA Lepidium meyenii", 2003;
http://www.odporen.com/files/pdf/si_610_p1.pdf
compared favorably with: Certified Organic Maca Root Product: Whole Raw Powder, Maca Root Nutritional Info; http://www.rawganique.com/maca.htm
See also: http://macasure.com/about-maca/nutritional-profile.html
Maca root has all essential amino acids in at least ideal proportions, except tryptophan; no data found for that amino acid.
** near complete protein; lysine 1.14, meth+cys 1.32, tryptophan 0.70 -- based on commercially available maca root powder: Grupo Prodivin do Brazil Ltda.;
http://prodivin.galeon.com/productos813843.html

Maize (corn)
Adjusted yield, due to combine losses and moisture losses, estimated based on:
McNeill and Montross, "Corn Harvesting, Handling, Drying, and Storage", Mississippi Extension Service and Experiment Station, Mississippi State University;
http://msucares.com/pubs/publications/p2285.pdf
Maize high yield estimates based on FAOSTAT 2009 USA data (10,339 kg/ha) for "maize", and compared with: Lee and Herbek, "Estimating Corn Yields", University of Kentucky, College of Agriculture, 2005; http://www.ca.uky.edu/agc/pubs/agr/agr187/agr187.pdf
The higher FAO yields (17 t/ha) for green maize apparently include the cob.
Maize low yield estimates based on world average yield from FAOSTAT 2009 for maize (not green maize) is 5,162 kg/ha.
USDA Nutrient data (SR24) used for: "Corn flour, whole-grain, yellow"
* incomplete protein; lysine 0.55, meth+cys 1.56, tryptophan 1.01.
Maize is an incomplete protein, with lysine at 0.55 of ideal; it is low in total protein at about 7%.
The corn with the highest protein, in the USDA database, is "Cornmeal, white (Navajo)" with total protein at 10.99% and lysine at 0.57 of ideal.

Maize QPM
quality protein maize
QPM has the same percentages of protein, fat, and carbs as other maize.
USDA Nutrient data (SR24) used for: "Corn flour, whole-grain, yellow"; Essential amino acids analysis from: Brown, et al., Quality Protein Maize, National Research Council, National Academy of Sciences, 1988; TABLE 6.3 Amino Acid Content of Processed Foods Made with QPM; http://books.google.com/books/download/Quality_protein_maize.pdf
** quality protein maize is a near complete protein; lysine 0.82 (IOM) or 0.93 (FAO/WHO); meth+cys 1.56; tryptophan 1.23.

Maize oil
corn oil
Oil yield (172 liters/ha) converted to kg/ha assuming oil has specific density of 0.92 (158 kg/ha).
Oil yield from:
Journey To Forever, "Oil yields and characteristics"; "These are conservative estimates -- crop yields vary widely. This data is compiled from a variety of sources. Where sources vary averages are given." http://journeytoforever.org/biodiesel_yield.html

Marama bean
Tylosema esculentum
Lost Crops of Africa, Volume II, Vegetables, p. 235, as follows:
Very drought tolerant, due to a large underground tuber that stores water, for use when the season is dry. Tolerant to both very hot weather and freezing cold weather. Can be pressed for oil. Both the beans and the tubers are edible. Beans are approx. 34.5% protein, 39.5% fat (average of numbers from Lost Crops of Africa, Volume II, Vegetables, p. 238). No information on yield, but time to maturity is said to be 2 to 4 years.
Yield (805 kg/ha) estimated from Bambara beans FAOSTAT 2009 world data, because both beans are grown in Africa, and both are underdeveloped crops.
Carbs estimated at 16%, and fiber estimated at 8.5%, by comparison with peanut, which has about the same value for protein plus fat.
Insufficient information on essential amino acids; "rich in lysine (5 percent) and deficient in methionine...." Lost Crops of Africa, Volume II, p. 239.

Mashua
Tropaeolum tuberosum, also called isaño
Lost Crops of the Incas, p. 69, macronutrient data:
Dry matter is: 11.4 g protein, 4.3 g fat, 78.6 g carbohydrate per 100 g.
Calculation for raw tuber at 80% water: 2.28% protein, 0.86% fat, 15.72% carbohydrate.
Yield of "between 20 and 30 tons per hectare" from:
Lost Crops of the Incas, p. 70.
Time to maturity from:
S. Bala Ravi, et al., Hunger and Poverty: the role of biodiversity, p. 114;
Oca, ulluco, and isana [Tropaeolum tuberosum] ... "have a long cycle of 6 months or more."
http://www.unscn.org/layout/modules/resources/files/Hunger_and_poverty_The_role_of_biodiversity.pdf
Fiber from: Felipe Artemio Surco Laos, "Caracterización de almidones aislados de tubérculos andinos: mashua (Tropaeolum tuberosum), oca (Oxalis tuberosa), olluco (Ullucus tuberosus) para su aplicación tecnológica", 2004;
http://www.cybertesis.edu.pe/sisbib/2004/surco_lf/html/sdx/surco_lf.html

Mesquite pods (flour)
Ratio of pods to flour from: Desert Harvesters, "Mesquite Harvesting & Processing", Excerpted from 'The Tumbleweed Gourmet' by Carolyn J. Niethammer;
http://www.desertharvesters.org/mesquite-in-the-kitchen/harvesting-processing/
Yield from: Jose Villanueva-Diazl, et al., "Mesquite: A Multi-Purpose Species in Two Locations of San Luis Potosi, Mexico", USDA Forest Service Proceedings RMRS-P-13. 2000;
http://www.fs.fed.us/rm/pubs/rmrs_p013/rmrs_p013_268_272.pdf
Protein, fat, carbohydrates, fiber from: Gibson, et al., "Mesquite," Medicinal Plants of the Southwest, 2001; http://medplant.nmsu.edu/mesquite4.shtm

Millet
Yield (1887 kg/ha) from FAOSTAT 2009 USA data.
USDA Nutrient data (SR24) used for "Millet, raw"
Production quantity reduced by 25%, as a rough estimate of percentage of hulls (comparable to oats and barley).
* incomplete protein; lysine 0.38, meth+cys 1.57, tryptophan 1.54; total protein is 11.02 per USDA SR24.
Millet has a substantial deficit of lysine at only 0.38 of ideal. This level of lysine is much lower than other grains (at 0.212 g/ 100 g of raw grain), even lower than yellow whole-grain cornmeal (0.228 g/100 g food). Millet needs improvement in lysine content in order to be a suitable staple crop for the world.

Mauka
Mirabilis expansa
Lost Crops of the Incas, p. 77:
Normal yield of 20 tons per hectare, with up to 12 months to maturity; yields of 50 tons with 24 month maturity.
Dry weight basis: protein 7%, carbohydrate 87%.
Fat estimated at 2% on a dry weigh basis, per:
Fuccillo, et al., "Biodiversity in Trust, Conservation and Use of Plant Genetic Resources in Cgiar Centres," 1997;
"higher levels of fat that other ARTC crops [Andean Root and Tuber Crops], except for maca"
http://books.google.com/books?id=jLOiSPWy518C
Maca is 2.2% fat on a dry weight basis, so mauka is estimated at 2%.
Calculation for raw tuber at 80% water: protein 1.40%, fat 0.40%, carbs 17.40%.
No information on essential amino acid profile.
Fiber taken from similar crop: Mashua.

Mongongo nut
Schinzophyton rauteneii, Manketti nut
fat and protein content from:
Natural Food Guide, "The Mongongo/Manketti Nut", Ricinodendron rautanenii (Schinziophyton rautanenii)
http://www.naturalhub.com/natural_food_guide_nuts_uncommon_Ricinodendron_rautanenii.htm
Carb and fiber content estimated by comparison with other nuts, especially black walnuts, which have almost the same protein and fat content.
Yield estimated from:

F. P. Graz, "Description and Ecology of Schinziophyton rautanenii (Schinz)," Department of Agriculture, Polytechnic of Namibia, 2002, p. 25, 27; "Peters (1987) provides a more quantitative estimate of fruit yield of between 200 and 800 kg per hectare, while Keegan (1982) mentions 1 t of nuts per hectare for some stands north of Tsumeb in northern Namibia."
The nut is said to be 9.0% of the total fruit weight, but it is unclear how much of that weight is the inedible shell. I've estimated the percent of the shell at 60% by comparison with hazelnuts (which it is said to resemble).
http://www.nbri.org.na/fileadmin/user_upload/publications/Dinteria/d27-3-Graz-W.pdf
Stated yield of 200 to 800 to 1,000 kg per ha averaged as 600 kg/ha, times 9% for the weight of the nut, times 40% for the weight of the kernel, gives us a yield of only 21.6 kg/ha. Even at 1000 kg/ha for the fruit, the kernel weight would only be 3.6% of the fruit yield or 90 kg, giving us only 36 kg/ha of kernels.

Moringa tree
Moringa oleifera
nutritional content from: Martin L. Price, The Moringa Tree, ECHO Technical Note; Published 1985; Revised 2000, 2002, 2007 by ECHO Staff;
immature pods: protein 2.5%, fat 0.1%, carbs 3.7%, fiber 4.8% (Note that total carbs was taken as carbs plus fiber (3.7 + 4.8 = 8.5%) because the stated carb value is less than the fiber.
leaves: protein 6.7%, fat 1.7%, carbs 13.4%
mature seeds: 40% fat
http://chenetwork.org/files_pdf/Moringa.pdf
According to Lost Crops of Africa, the pods provide "a good balance of all the essential amino acids" (p. 248).
No yield data found; yield estimated from mesquite pods (another tree that produces edible pods).

Mung bean
Phaseolus mungo
Yield (2000 lb/ac) and time to maturity (3 to 4 mo.) from: Oplinger, et al., "Mung Bean", Alternative Field Crops Manual; http://www.hort.purdue.edu/newcrop/afcm/mungbean.html
USDA Nutrient data (SR24) used for "Mung beans, mature seeds, raw"
Production quantity not reduced for mature seeds (reported by clean dry weight).
** near complete protein; lysine 1.37, meth+cys 0.83, tryptophan 1.56

Mushroom
Yield (300 t/ha) estimated from USDA Economic Research Service (Table 8)
http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1395
2009/2010 yield of 6 lbs/sq ft. converted to 292,945 kg/ha,
2010/2011 yield of 6.32 lbs/sq ft. converted to 308,569 kg/ha,
and from:
FAOSTAT 2009 World data (333,446 kg/ha)
Time to maturity is given as 12 months because production of mushrooms is a continuous process, indoors and year-round.
USDA Nutrient data (SR24) used for "Mushrooms, white, raw"
"Refuse: 3% Refuse Description: Trimmings"
Production quantity reduced by 10% to account for cleaning and trimmings
* incomplete protein; lysine 0.68, meth+cys 0.56, tryptophan 1.62, leucine 0.71, phenyl+tyro 0.89

Noog

Nigerseed, Guizotia abyssinica
Seed yield (1255 kg/ha) from:
Quinn and Myers, "Nigerseed: Specialty Grain Opportunity for Midwestern U.S.", In: J. Janick and A. Whipkey, editors, Trends in New Crops and New Uses, (ASHS Press, Alexandria, VA).
http://www.hort.purdue.edu/newcrop/ncnu02/v5-174.html
Oil yield estimated at 40% based on range of data from:
FAO, Minor Oil Crops, "Noog abyssinia";
http://www.fao.org/docrep/X5043E/x5043E0a.htm

Oats
Yield (2421 kg/ha) from FAOSTAT 2009 USA data.
USDA Nutrient data (SR24) used for "Oats"
** near complete protein; lysine 0.81, meth+cys 1.71, tryptophan 1.98
Essential amino acid data from USDA SR24 (not bitterpoison.com).
Oats have a high total protein (higher than rice and wheat), and so the less than ideal percent of lysine is not problematic. Oats yields are disappointing, for such an excellent staple crop. Further research and development is needed. Perhaps an SRI approach (system of rice intensification) would increase yields.

Oca
Oxalis tuberosa
Yield and time to harvest estimated from:
National Research Council, Lost Crops of the Incas, "Oca", p. 88.
Macronutrient data estimated from:
National Research Council, Lost Crops of the Incas, "Oca", p. 87.
"9 percent on a dry-weight basis" at 80 percent moisture, gives: 1.8% protein.
Data on essential amino acid not found, except for this assertion from Lost Crops of the Incas, p. 87: "a good balance of essential amino acids (valine and tryptophan are the limiting ones)."
The presence of high amounts of oxalates limits the usefulness of this crop as a world staple food.
Fiber from: Felipe Artemio Surco Laos, "Caracterización de almidones aislados de tubérculos andinos: mashua (Tropaeolum tuberosum), oca (Oxalis tuberosa), olluco (Ullucus tuberosus) para su aplicación tecnológica", 2004;
http://www.cybertesis.edu.pe/sisbib/2004/surco_lf/html/sdx/surco_lf.html

Okra
Low yield of 4000 lbs/acre and high yield of 12000 lbs/acre (converted to kg/ha) from:
Butler and Spence, "Growing Okra", Maryland Cooperative Extension Fact Sheet;
http://extension.umd.edu/publications/pdfs/fs466.pdf
USDA Nutrient data (SR24) used for "Okra, raw "
"Refuse: 14% Refuse Description: Crown and tips"
Production quantity reduced by 14% (to 86%)
** near complete protein; lysine 0.79, meth+cys 0.80, tryptophan 1.21, leucine 0.95

Olive oil
USDA Nutrient data (SR24) used for "Oil, olive, salad or cooking"
Fruit yields and oil as a percentage of fruit vary greatly.
Typical oil content ranges from about 15 to 20%, and average is 17.5%, per:
Barrio and Carman, Olive Oil: A 'Rediscovered' California Crop, Giannini Foundation of Agricultural Economics, Vol. 8 No. 5 May/June 2005;

http://www.agmrc.org/media/cms/v8n5_1_3BA24B154D422.pdf
Typical fruit yields can range from 1 to 6 tons per acre, with 2 to 4 tons being more typical, and the average is 3 tons per acre (6725 kg/ha), per:
'First Press - Newsletter of Olive Oil Production and Evaluation,' Fall 2006, Table 1. Orchard Yield Projections for Oil Olives.
http://cesonoma.ucdavis.edu/files/27239.pdf
Calculating the oil from the fruit: 17.5% of 6725 kg/ha is 1177 kg of oil/ha.
These numbers are approximate, but in the same range as in other sources.

Onions
Time to maturity estimated from 2011 Seed Savers Yearbook.
Yield from: FAOSTAT 2009 USA data (56071 kg/ha)
USDA Nutrient data (SR24) used for: "Onions, raw"
"Refuse: 10% Refuse Description: Stem ends, sprouts and defects"
* incomplete protein; no essential amino acid over 0.75 except arginine 5.25 and tryptophan 1.82

Palm Fruit Oil
Fruit production quantity from FAOSTAT 2009 world data: 210,326,644 t/ha
Fruit area harvested from same: 14,921,224 ha
Fruit yield from same: 14.096 t/ha
Oil production quantity from FAOSTAT (crops processed) 2009: 45,083,932 metric tonnes (t)
Oil yield calculated from above: 0.214 t/ha
This figure is too low, given that palm fruit is "56 percent oil (25 percent on a fresh fruit bunch basis)" per:
Kwasi Poku, "Small-Scale Palm Oil Processing in Africa", 2. Oil Palm, FAO Corporate Document Repository;
http://www.fao.org/DOCREP/005/Y4355E/y4355e03.htm
Calculation of oil yield: fruit yield of 14096 kg/ha times 25 percent oil in fruit equals 3524 kg/ha yield of oil.

Palm Kernel Oil
Palm kernel oil production, FAOSTAT 2009 Crops processed: 5,733,908 tonnes per year
Yield stated in FAOSTAT 2009 includes "oil of babassu kernels," so that yield is not accurate for palm kernel oil alone.
Yield calculated from:
Food and Nutrition Bulletin Volume 15, Number 2, 1993/1994 (UNU, 1993/1994, 72 p.)
http://www.nzdl.org/gsdlmod
"The oil palm is the most prolific oil-producing plant; the national average oil yield in Malaysia is 3.8 tons per hectare per year, with 11% of that quantity being palm kernel oil, a co-product."
Calculation: 11% of 3800 kg/ha-yr equals 418 kg/ha-yr

Parsnips
Yield (25 t/ha) from: Prince Edward Island, Department of Agriculture and Forestry, "Parsnip Introduction"; "Parsnip yields are over 20,000 to 30,000 kg per hectare."
http://www.gov.pe.ca/af/agweb/index.php3?number=70453
USDA Nutrient data (SR24) used for "Parsnips, raw" -- "Refuse: 15% Refuse Description: Parings"
Production quantity reduced by 15%
No essential amino acid information found

Peanut (ground nut)
USDA Nutrient data (SR24) used for "Peanuts, all types, raw"
Yield from FAOSTAT 2009 USA
FAO Metadata classification states: "For trade data, groundnuts in shell are converted at 70% and reported on a shelled basis."
http://faostat.fao.org/site/384/default.aspx
Since FAOSTAT data is for "groundnuts, with shell", production quantity reduced by 30% to account for shells.
** near complete protein; lysine 0.70, meth+cys 1.00, tryptophan 1.38.
Peanut is much higher in protein (at 25.8%) than any grains, and so the amount of lysine per 100 g of food is much higher (0.926 g) than grains with a complete essential amino acid profile (lysine at or above 1.00).

Peas dry
Time to harvest from SSE 2011 Yearbook, Pea/Soup.
Yield (2292 kg/ha) from FAOSTAT 2009 USA.
USDA Nutrient data (SR24) used for: "Peas, split, mature seeds, raw" (11.27% water)
*** complete protein (unlike fresh peas: "peas green"); lysine 1.42, meth+cys 1.02, tryptophan 1.60.

Peas green
Time to harvest from SSE 2011 Yearbook, Pea/Garden.
Yield (11414 kg/ha) from FAOSTAT 2009 USA.
USDA Nutrient data (SR24) used for: "Peas, green, raw" (78.86% water)
** near complete protein; lysine 1.15, meth+cys 0.84, tryptophan 0.98.

Peas edible-pod
Time to harvest from SSE 2011 Yearbook, Pea/Pod.
Yield (5828 kg/ha) from:
Mark Gaskell, "Edible-Pod Pea Production in California", University of California, Division of Agriculture and Natural Resources, publication 7233;
http://www.ucanr.org/freepubs/docs/7233.pdf
USDA Nutrient data (SR24) used for: "Peas, edible-podded, raw"
"Refuse: 6% Refuse Description: Ends and strings"
* incomplete protein; lysine 1.41, meth+cys 0.61, tryptophan 1.38

Peppers PC
Yield from FAOSTAT 2009 USA data: 30,719 kg/ha.
USDA Nutrient data (SR24) used for "Peppers, sweet, green, raw"
"Refuse: 18% Refuse Description: Stem ends, seeds and core"
Production quantity not reduced since whole produce is used in protein concentrate
** near complete protein; lysine 0.89, meth+cys 0.88, tryptophan 1.99, leucine 0.76

Perilla oil
Data sources:
NewCROP Factsheet, "Perilla";
Seed Yield: "The average seed yield in Korea is 770 kg/ha in commercial production (Lee et al. 1989) although research plots can yield twice as much (summarized by Brenner 1993)."
Oil composition: "The high linolenic content of the oil (64%) makes it unstable due to oxidation"
www.hort.purdue.edu/newcrop/cropfactsheets/perilla.pdf

David M. Brenner, "Perilla: Botany, Uses and Genetic Resources", 1993;
Oil yield: "The seeds of perilla contain 31 to 51% of a drying oil similar to tung or linseed oil (Jamieson 1943)."
Toxicology: "Perilla is ordinarily avoided by cattle but has been implicated in cattle poisoning (Phillips and Von Tungein 1986). Plants are most toxic if cut and dried for hay late in the summer, during seed production (Kerr et al. 1986). Wilson et al. (1977) isolated the toxin "perilla ketone," which causes pulmonary edema (fluid in the lung cavity) in many animal species, although not in pigs or dogs (Garst et al. 1985). In Japan, 20 to 50% of long-term workers in the perilla industry develop dermatitis on their hands due to contact with perillaldehyde (Okazaki et al. 1982). "
http://www.hort.purdue.edu/newcrop/proceedings1993/v2-322.html
Evaluation: Perilla oil is not suitable as a source for staple dietary fat, due to questions about toxicity, low yields, and the oxidation instability (it goes rancid quickly).

Pigeon peas
Cajanus cajan, red gram
Low yield from FAOSTAT World data: 769 kg/ha
High yield and time to maturity from:
James Duke, "Cajanus cajan (L.) Millsp.", Handbook of Energy Crops, 1983;
"Dried seed yields may reach 2,500 kg/ha in pure stands, but average yields are closer to 600 kg/ha."
http://www.hort.purdue.edu/newcrop/duke_energy/Cajanus_cajun.html
USDA Nutrient data (SR24) used for: "Pigeon peas (red gram), mature seeds, raw"
*** complete protein; lysine 1.37, meth+cys 0.91, tryptophan 1.40.

Pili nuts
Canarium ovatum, commonly known as pili, a species of tropical tree
USDA Nutrient data (SR24) used for: "Nuts, pilinuts, dried"
"Refuse: 81% Refuse Description: Shells"
Philipines, Sorsogon Provincial Tourism Council:
"The Province of Sorsogon has been declared the 'commodity champion' for Pili nut because it is the biggest Pili production source in the whole Bicol Region, accounting for approximately 70% of the total Pili supply in the country. It has a total of 1,568.54 hectares planted to Pili trees, or an estimated total of 56,861 trees capable of producing 1,893 metric tons of Pili nuts per harvest season."
http://www.sorsogontourism.com/business_opportunities.htm
Calculation from above: 36 trees per hectare; 1200 kg/ha; 33 kg of kernels per tree per year.
This per tree yield is confirmed by: "Pili Nuts and Its Uses";
http://www.pinoybisnes.com/agri-business/pili-nuts-and-its-uses/
and by: FAO, "Minor Oil Crops";
http://www.fao.org/docrep/X5043E/x5043E0a.htm
Yield of pili nuts with shell is as high as 150 kg per tree. Given that the USDA database lists the shell as a high percentage of the total weight, these numbers all make sense: 150 kg per tree in shell, 33 kg per tree for the shelled kernels.
* incomplete protein; lysine 0.67, meth+cys 2.16, tryptophan 2.50; total protein: 10.8% Note: with a high level of both methionine and tryptophan, this protein source is a good complement to any food high in lysine.
Macronutrient and fiber data from: James A. Duke, "Handbook of Nuts: Herbal Reference Library", p. 67.

Pistachios
Yield from FAOSTAT 2009 World data
USDA Nutrient data (SR24) used for: "Nuts, pistachio nuts, raw"
"Refuse: 47% Refuse Description: Shells"
Yield reduced by 47% to 53%
*** complete protein; lysine 1.10, meth+cys 1.35, tryptophan 1.89; total protein 20.27%

Plantains
Yield from FAOSTAT 2009 World data
USDA Nutrient data (SR24) used for: "Plantains, raw"
"Refuse: 35% (Skin and stems)"
Yield reduced by 35% (to 65%) to account for skin and stems.
Plantains are mainly a carbohydrate staple crop.
** near complete protein; lysine 0.90, meth+cys 1.14, tryptophan 1.65, Leucine 0.83, Threonine 0.97; total protein 1.3%

Potato
USDA Nutrient data (SR24) used for: "Potato, flesh and skin, raw"
"Refuse: 25% Refuse Description: Parings and trimmings"
Yield from FAOSTAT 2009 USA data.
Yield reduced by 25% to account for pairings and trimmings.
*** complete protein; lysine 1.22, meth+cys 1.17, tryptophan 2.26.

Pumpkin flesh
USDA Nutrient data (SR24) used for: "Pumpkin, raw"
"Refuse: 30% Refuse Description: Seeds, rind and stem"
Yield reduced by 30% to 70%.
Ideal yield (100,000 kg/ha) estimated conservatively from: Kelley, et al., "Huge Yields, Huge Differences in Georgia-North Carolina Pumpkin Variety Trials", 2007;
http://www.caes.uga.edu/commodities/fruits/veg/pubs/2007%20Ext%20Rpt/documents/kelley86-88.pdf
Trials 20 varieties of large pumpkins had an average yield of 91,827 lb/ac, which is 102,924 kg/ha; six of those varieties yielded over 120,000 kg/ha.
Low yield from FAOSTAT 2009 USA data for "Pumpkins, squash and gourds"
* incomplete protein; lysine 1.06, meth+cys 0.56, tryptophan 1.71; Leucine 0.84.

Pumpkin seeds
USDA Nutrient data (SR24) used for: "Seeds, pumpkin and squash seed kernels, dried"
"Refuse: 26% Refuse Description: Hulls"
Seed yield reduced by 26% (to 74%) to account for hulls; but ideal pumpkin seed assumes hulless seeds and so is not reduced.
Ideal seed yield of hulless seeds estimated at 4% based on:
Bavec, F., L. Gril, S. Grobelnik-Mlakar, and M. Bavec. 2002. "Production of pumpkin for oil." p. 187-193. In: J. Janick and A. Whipkey (eds.), Trends in new crops and new uses. ASHS Press, Alexandria, VA.
Above source showed typical seed yields of 3 to 4% (50% water), and as high as over 7% of total weight of pumpkin. Seed weights reduced by 45% (to 55%) to account for drying of seeds to 10% moisture.

Low yield from FAOSTAT 2009 World data for "Melonseed" which is "Cucumis melo. Includes seeds of other Cucurbitaceae."
*** complete protein; lysine 1.46, meth+cys 1.39, tryptophan 2.51.

Pumpkin seed oil
Fruhwirth and Hermetter, "Seeds and oil of the Styrian oil pumpkin: Components and biological activities", European Journal of Lipid Science and Technology, Volume: 109, Issue: 11, Pages: 1128-1140, 2007;
"Styrian pumpkin seed oil is also of considerable economical importance for the province of Styria. The so-called oil pumpkin is the third most important field fruit in Styria with 13,000 ha of cultivable land yielding 11,100 tons in the year 2006 [15]. The average yield of pumpkin seeds of this variety strongly depends on the weather conditions, ranging from approximately 400 kg/ha (under drought) up to 1000 kg/ha under optimal conditions, with an average yield of 500-600 kg/ha. For the production of 1 L of this specialty oil, an average of 2.5 kg of pumpkin seeds is required, which corresponds to an amount of 30-40 oil pumpkins."
http://www.mendeley.com/research/seeds-oil-styrian-oil-pumpkin-components-biological-activities/#
Calculations:
Low yield: 400 (kg seed per ha) divided by (2.5 kg per liter) = 160 liters oil per ha
(160 liters oil) times (oil density estimate of 0.92 kg/liter) = 147.2 kg oil/ha
Average yield: 202.4 kg oil/ha
High yield: 368.0 kg oil/ha

Quinoa Grain
USDA Nutrient data (SR24) used for: "Quinoa, uncooked"
Yield (1800 kg/ha) estimated from:
Oelke1, et al., "Quinoa", Alternative Field Crops Manual;
http://www.hort.purdue.edu/newcrop/afcm/quinoa.html
Essential amino acid data from USDA SR24.
*** complete protein; lysine 1.06, meth+cys 1.45, tryptophan 1.69.
Quinoa is high in total protein, at over 14%, and high in total lysine per 100 g of food. It is one of the best grain sources of protein.

Quinoa Leaf PC
Leaf yield and nutritional content take from Amaranth leaf; no other data available.

Rapeseed oil
Canola oil
Seed yield from FAOSTAT 2009 USA data.
Oil yield from seed calculated from:
CanolaInfo - What is Canola Oil?, "Processing Canola Oil";
http://www.canolainfo.org/canola/index.php?page=6
Canola seed is 42% oil, and the extraction efficiency is 96% (0.42 x 0.96 = 0.40).
Time to harvest from:
Sergio Muñoz-Valenzuela and Andrew Easton, "Evaluaton of Canola Lines in the Utah Valley," In: Issues in new crops and new uses, 2007;
http://www.hort.purdue.edu/newcrop/ncnu07/pdfs/munoz190-192.pdf

Rice (Asian)

Low yield (4329 kg/ha) from FAOSTAT 2009 World data for "rice, paddy"
High yield (7941 kg/ha) from FAOSTAT 2009 USA data for "rice, paddy"
USDA Nutrient data (SR24) data for "Rice, white, long-grain, regular, raw, enriched".
Essential amino acids analysis from BitterPoison.com
** near complete protein; lysine 0.71, meth+cys 1.76, tryptophan 1.66.

Rice (Nerica)
New Rice for Africa, a cross between Asian rice and African wild rice; higher in protein than Asian rice, but with much the same essential amino acids profile (considered as percentages). Different varieties of Nerica have different percentages of protein, ranging from 9 to 11% protein, per:
Africa Rice Center, "Module 13 NERICA Grain and Nutritional Quality", p. 118;
"NERICA rice prepared by the parboiling method has higher average protein (10.7%) and amino acid balance than directly milled NERICA rice (10.2%)."
http://www.africarice.org/warda/guide-compend.asp
Fat and Carb data from USDA Nutrient data (SR24) data for "Rice, white, long-grain, regular, raw, enriched".
Yields from Rice (Asian) above.
High yield potential verified from:
Krupnik, et al., "Trade-offs between rice yield, weed competition and water use in the Senegal River Valley", 2010;
"NERICA-L 55" using conventional crop management practices produced 7.93 t/ha of grain;
http://www.africarice.org/workshop/ARC/2.3%20Krupnik%20ed2.pdf
** near complete protein; lysine 0.78, meth+cys 1.24, tryptophan 1.85
Like Asian rice, Nerica is a good source of all essential amino acids except lysine. But the total protein, percent lysine, and total lysine are each significantly higher in Nerica than in Asian rice.
Essential amino acid content of Nerica1 from:
http://www.africarice.org/publications/nerica-comp/module%2013_Low.pdf
which gives the essential amino acid content per 100 g of food, and the total protein content per 100 g of food.

Rutabaga
Yield (44 t/ha) estimated from: Douglas C. Sanders, "Turnips and Rutabagas", 2001; 400 cwt/acre converted to t/ha is 44 t/ha; http://www.ces.ncsu.edu/depts/hort/hil/hil-26.html
See also: Soil Conservation Council of Canada, "Compost helps boost NL vegetable yield by nearly 60 percent"; http://www.soilcc.ca/ggmp_region/nl-01.php
Time to maturity estimated from Seed Savers Exchange 2011 Yearbook
USDA Nutrient data (SR24) used for "Rutabagas, raw" -- "Refuse: 15% Refuse Description: Parings"
Production quantity reduced by 15% (to 85%)
* incomplete protein; lysine 0.64, leucine 0.58, meth+cys 0.70, tryptophan 1.55

Rye
Yield (2431 kg/ha) from FAOSTAT 2009 Canada data.
Reduction in yield from hulling and milling of grain estimated from barley, taking into account that light rye involves more milling losses.
USDA Nutrient data (SR24) used for "Rye flour, light"
Rye is usually planted in fall, for harvest in spring. But time needed for cereal rye to reach maturity is estimated at 120 days or less.
* incomplete protein; lysine 0.42, methionine 0.46, tryptophan 1.61.

Essential amino acid profile calculated from USDA SR24 data, which is from ConAgra Inc. It is unusual for any grain to be so low in both methionine and lysine. Also, no cysteine is reported at all in the data, which may explain low meth+cys value.

Sacha Inchi oil
The oil content in the sacha inchi varieties used for oil is higher than in other varieties, as high as 54% per:
HerbDealer.com, "Sacha Inchi Oil", http://www.sacha-inchi-oil.com
The yield (4000 kg/ha) cited on that website is high compared to other sources, so two figures are used in this analysis 2000 kg/ha and 4000 kg/ha. Another source gives 54.3% for the oil content, but different values for the constituent types of fat in the oil, so that figure is an independent confirmation:
Follegatti-Romero, et. al., "Supercritical CO2 extraction of omega-3 rich oil from Sacha inchi (Plukenetia volubilis L.) seeds", 27 March 2009;
http://www.sciencedirect.com/science/article/pii/S0896844609001119
The efficiency of oil extraction for a small cold press would generally be in the range of 75 to 85%, according to various examples of similar oil seeds at:
Piteba, "Performance of the PITEBA OIL EXPELLER with various oilseeds";
http://www.piteba.com/eng/performance.htm
The figure of 12 months is used for the time to crop maturity because sacha inchi offers a continuous year-round harvest. Yield figures are per year.

Sacha Inchi seed
Low yield estimate (2.0 t/ha) from:
Ing. Emma I. Manco Céspedes "Cultivo De Sacha Inchi", Peru, 2006;
http://www.incainchi.es/pdf/1358.pdf
Protein, fat, and carbohydrate percentages from:
Gutiérrez, et al., "Chemical composition of Sacha Inchi (Plukenetia volubilis L.) seeds and characteristics of their lipid fraction", 2011;
http://grasasyaceites.revistas.csic.es/index.php/grasasyaceites/article/download/1301/1300
Essential amino acids analysis from:
Hamaker, et al., "Amino Acid and Fatty Acid Profiles of the Inca Peanut (Plukenetia volubilis)", Table 1, 1992;
http://www.aaccnet.org/publications/cc/backissues/1992/Documents/69_461.pdf
** near complete protein; lysine 0.84, meth+cys 1.48, tryptophan 4.14.
Sacha inchi is an excellent source of protein; lysine is at 0.84 of ideal, but the total protein is so high (24.7%) that sacha inchi seeds provide 1.06 g of lysine per 100 g of food, which is three times what rice provides. Sacha inchi is also one of the best sources of tryptophan at 4.14 times the IOM ideal.
Fiber per 100 grams calculated from commercial product US nutrition label: "Vega SaviSeed - Oh Natural Pouch", 5 grams fiber per one ounce (28 grams), http://shop.myvega.com/sequel-estore-us/Graceful-Aging_2/vega-saviseed-oh-natural-pouch-usa

Safflower kernels and oil
Yield (1639 kg/ha) from FAOSTAT 2009 USA.
Oil percentages and yield data taken from, or compared to:
Beyyavas, "Determination of seed yield and yield components of some safflower (Carthamus tinctorius L.) Cultivars, Lines and Populations under the Semi-Arid Conditions", African Journal of Biotechnology Vol. 10 (4), pp. 527-534, 24 January, 2011;
http://www.academicjournals.org/AJB/PDF/pdf2011/24Jan/Beyyavas%20et%20al.pdf

Time to maturity (~5 months) from:
Berglund, et al., "Safflower Production", A-870 (Revised), August 2007;
http://www.ag.ndsu.edu/pubs/plantsci/crops/a870w.htm
USDA Nutrient data (SR24) used for: "Seeds, safflower seed kernels, dried"
"Refuse: 49% (Hulls)"
Essential amino acids analysis from BitterPoison.com "Seeds, safflower seed kernels, dried"
* incomplete protein; lysine 0.65, meth+cys 1.47, tryptophan 1.62.
Fiber in kernels from: Kohler, et al., "Safflower meal", Journal of the American Oil Chemists' Society, Volume 43, Number 6 (1966), 413-415, DOI: 10.1007/BF02646802 --
http://www.springerlink.com/content/b4333793658t2u7t/

Salicornia oil
(glasswort)
Oilseed yield 0.2 kg oilseed/sq m, which is 2000 kg/ha, from:
Edward P. Glenn, et al., "Irrigating Crops with Seawater", Scientific American, August 1998;
"During six years of field trials in Mexico, Salicornia produced an average annual crop of 1.7 kilograms per square meter of total biomass and 0.2 kilogram per square meter of oilseed."
http://www.miracosta.edu/home/kmeldahl/articles/crops.pdf
Oilseed is 30% oil, so yield is reduced by 70%, per:
The Hindu, "Salicornia, oil-yielding plant for coastal belts", 5 Sept. 2003;
http://www.hindu.com/seta/2003/09/05/stories/2003090500300300.htm
Time to maturity (seven months) from:
Anne Charnock, "Plants with a Taste for Salt", New Scientist - Dec 3, 1988 - Google Books (p. 41)
http://books.google.com/books?id=5vrK5-QtVLwC

Salsify
Tragopogon porrifolius
USDA Nutrient data (SR24) used for: "Salsify, (vegetable oyster), raw"
"13% (Scrapings and rootlets)"
Time to harvest (100 to 120 days) from SSE Yearbook 2011
Yield (15 to 20 t/ha) from related plant ('Spanish salsify')
http://en.wikipedia.org/wiki/Scorzonera_hispanica
Essential amino acids information not found.
Fiber estimated from content of inulin and oligofructose: Coussement, "Inulin and oligofructose as dietary fiber", in: Complex Carbohydrates in Foods, Cho et al., editors;
http://books.google.com/books?hl=en&lr=&id=foa9l-rQQLMC

Scorzonera
Scorzonera hispanica
Yield (15 to 20 t/ha) from:
http://en.wikipedia.org/wiki/Scorzonera_hispanica
Nutrient data not found.
Essential amino acids information not found.

Sesame seed
Yield (1000 kg/ha) converted from 900 lb/acre in:
"Growing Sesame: Production tips, economics, and more", Thomas Jefferson Agricultural Institute;
"Typical test plot yields in Missouri during 1992-1994 were 800 to 1000 pounds per acre, with maximum yields of 1200 pounds on small research plots."

http://www.jeffersoninstitute.org/pubs/sesame.shtml
Yield reduced by 15% to account for hulls
M. T. Farran et al., Performance of broilers and Layers Fed Graded Levels of Sesame Hull, p. 1 (cites 12%);
http://japr.fass.org/cgi/reprint/9/4/453.pdf
B. D. Shukia et al., Oil Seeds Processing Technology, 1992 (cites 14-18%);
http://idl-bnc.idrc.ca/dspace/bitstream/10625/11596/1/95811.pdf
Time to harvest from:
Suhasini, "Characterization of Sesame Genotypes through Morphological, Chemical and RAPD Markers", master's thesis, College of Agriculture, Dharwad, India, 2006; and
Agricultural Marketing Resource Center, "Sesame Profile", Iowa State University, February 2005; "In commercial varieties, maturity occurs in 90 to 120 frost-free days."
http://www.agmrc.org/commodities__products/grains__oilseeds/sesame_profile.cfm
USDA Nutrient data (SR24) used for: "Seeds, sesame seeds, whole, dried"
* incomplete protein; lysine 0.63, meth+cys 2.13, tryptophan 3.13 relative to IOM standard (1.00).

Sesame seed oil
Oil extraction efficiency is highest when heat and/or solvents are used, reaching well over 90% efficiency. Here, the yield is reduced to 45% to account for a 90% efficiency and 49.67% oil content. Some producers hull the seed before pressing for oil; this results in a higher quality press cake, suitable for human food. Other producers press the seed without hulling; this results in a press cake that is most suitable for domesticated animals.

Sorghum grain
Yield (4355 kg/ha) from FAOSTAT 2009 USA data
Yield reduced by 15% to account for losses due to drying and hulling.
Days to maturity from:
Seed Inc. - Products - Grain Sorghum
http://www.seedinc.biz/Grain-Sorghum.html
USDA Nutrient data (SR24) used for: "Sorghum"
* incomplete protein; lysine is low at 0.40, meth+cys 1.05, tryptophan 1.57.

Sorghum sugar
Estimate of total sugar content in sorghum juice from:
FAO, Lu Nan, et al., "Ethanol production from sweet sorghum", In: Integrated energy systems in China - The cold Northeastern region experience, 1994;
http://www.fao.org/docrep/T4470E/t4470e07.htm
Estimate of dry matter yield from:
Undersander, et al., Alternative Field Crops Manual, University of Wisconsin, 1990;
http://www.hort.purdue.edu/newcrop/afcm/syrup.html

Soybeans
USDA Nutrient data (SR24) used for "Soybeans, mature seeds, raw"
Yield from FAOSTAT 2009 USA data
Production quantity not reduced because field weight excludes pods, per:
Soybean Harvesting, University of Arkansas, Division of Agriculture, Cooperative Extension Service;
http://www.aragriculture.org/crops/soybeans/harvesting.htm

Soybean oil
Yield (2958 kg/ha) from FAOSTAT 2009 USA data
NCSoy.org, "How Soybeans are Used", North Carolina Soybean Producers Association, 2011;
"When processed, a 60-pound bushel will yield about 11 pounds of crude soybean oil and 47 pounds of soybean meal. Soybeans are about 18% oil and 38% protein." [Calculation: 11/60 equals 18.3%]
http://www.ncsoy.org/ABOUT-SOYBEANS/Uses-of-Soybeans.aspx

Spelt
Yield (2737 kg/ha) converted from lb/ac of common Spelt in:
Oplinger, et al., "Spelt", Alternative Field Crops Manual, University of Wisconsin, 1990;
http://www.hort.purdue.edu/newcrop/afcm/spelt.html
and from:
Robyn Neeson, "Organic spelt production", NSW government publication, Australia, 2011;
"The average yields for the new cultivars (2.73 t/ha)"
http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0003/380784/Organic-spelt-production.pdf
Time to maturity based on 'champ' cultivar' (120 days).
USDA Nutrient data (SR24) used for: "Spelt, uncooked"
* incomplete protein; lysine 0.55, meth+cys 1.61, tryptophan 1.29

Spinach
Yield from FAOSTAT 2009 U.S.
Time to harvest from Seed Savers Exchange catalog
USDA Nutrient data (SR24) used for: "Spinach, raw"
Essential amino acids analysis from BitterPoison.com
*** complete protein; lysine 1.19, meth+cys 1.23, tryptophan 1.95

Squash/zucchini
several varieties, including zucchini
Yield from FAOSTAT 2009 U.S. data: 21052 kg/ha
Time to maturity varies greatly, estimated from 2011 Seedsaver Yearbook.
USDA Nutrient data (SR24) used for: "Squash, summer, zucchini, includes skin, raw"
"Refuse 5% Ends."
** near complete protein; lysine 1.09, meth+cys 0.99, tryptophan 1.18 , threonine 0.89.

Sugar beet
Yield (53,148 kg/ha) from FAOSTAT 2009 world data.
Yield reduced by 85.5% (to 14.5%) of FAO yield, per:
Saunders and Shock, "Sugar Beet Variety Trials 2009", Oregon State University, 2009;
Estimated recoverable sugar from multiple varieties/trials (Tables 1 and 2): approx. 290 lbs/ton, which equals 14.5%.
http://www.cropinfo.net/AnnualReports/2009/SugarBeetVariety2009.html
USDA Nutrient data (SR24) used for "Sugars, granulated"
Note: it is not clear how the carbohydrate content of reported quantities of partially processed beet sugar compares to "sugars granulated".

Sugar Beet PC
Yield and time to maturity from Sugar Beet
USDA Nutrient data (SR24) used for "Beets, raw"
but with only 5% refuse, since most of the crop can be processed into PC

** near complete protein; lysine 0.71, leucine 0.77, meth+cys 0.92.

Sugar cane
Yield (69,866 kg/ha) from FAOSTAT 2009 world data.
Yield reduced by 88.4% (to 11.6%) of FAO yield, per:
Baucum and Rice, "An Overview of Florida Sugarcane", Agronomy Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, 2006; "In Florida's sugarcane industry, recoverable sugar, by weight, has increased from below 10 percent in 1984 to 11.6 percent in 2000-01."; http://edis.ifas.ufl.edu/sc032
USDA Nutrient data (SR24) used for "Sugars, granulated"
Note: it is not clear how the carbohydrate content of reported quantities of partially processed cane sugar compares to "sugars granulated".

Sunflower seeds
Low yield from FAOSTAT 2009 USA data.
USDA Nutrient data (SR24) used for "Seeds, sunflower seed kernels, dried"
"Refuse: 46% (Hulls)"
Yield reduced by 46% (to 54%) to account for hulls.
High yield data from:
Sojka, et al., "Effect of Early and Late Planting on Sunflower Performance in the Southeastern United States", USDA Agricultural Research Service, 1989;
http://ddr.nal.usda.gov/bitstream/10113/18012/1/IND89008274.pdf
Additional yield data from:
Jefferson Institute, "Growing Sunflower: Production tips, economics, and more";
http://www.jeffersoninstitute.org/pubs/sunflower.shtml
** near complete protein; lysine 0.88, meth+cys 1.82, tryptophan 2.39

Sweet potatoes
Ipomoea batatas
Yield (22,520 kg/ha) from FAOSTAT 2009 USA data for sweet potatoes.
Yield reduced by 28% (to 72%) to account for pairings and trimmings.
Time to maturity from: B. Rosie Lerner, The Sweet Potato, Purdue University Cooperative Extension Service, revised 2001; http://www.hort.purdue.edu/ext/HO-136.pdf
USDA Nutrient data (SR24) used for: "Sweet potato, raw, unprepared"
"Refuse: 28% (Parings and trimmings)"
** near complete protein; lysine 0.82, meth+cys 1.30, tryptophan 2.82

Swiss chard
Yield and time to maturity from:
Kolota, et al., "Yield and Nutritional Value of Swiss Chard Grown for Summer and Autumn Harvest", Journal of Agricultural Science Vol. 2, No. 4; December 2010, average of five varieties from spring planting (61.74 t/ha, rounded to 60 t/ha);
http://ccsenet.org/journal/index.php/jas/article/view/5603
USDA Nutrient data (SR24) used for: "Chard, swiss, raw"
"Refuse: 8% Refuse Description: Tough stems and damaged leaves"
* incomplete protein; lysine 1.08, methionine 0.42, tryptophan 1.35, phenylalanine 1.30
data on methionine (only) and phenylalanine (only) calculated from SR24.

Taro

Colocasia esculenta, old cocoyam
Taro is not desirable as a staple food, due to the presence of high amounts of calcium oxalate. When the corms are peeled and boiled, and calcium is added as a supplement, taro is usable as a feedstock for poultry.
Hussain, et al., "Composition and nutritive value of cormels of Colocasia esculenta," Journal of the Science of Food and Agriculture;
"Crude protein amounted to 10.4% of the dry matter. This protein was low in the sulphur-containing amino acids [methionine and cysteine] and tryptophan, but contained adequate levels of the other essential amino acids."
http://onlinelibrary.wiley.com/doi/10.1002/jsfa.2740351010/abstract
Yield (10,056 kg/ha) from FAOSTAT 2009 USA data and
verified by comparison to yields in:
Peculiarities of Taro Production in Specific Asia-Pacific Countries
http://www.fao.org/docrep/005/ac450e/ac450e08.htm#b18-6.18%20Taro%20Cultivation%20in%20Japan
Time to maturity estimated from "Peculiarities..." above.
USDA Nutrient data (SR24) used for "Taro, raw "
"Refuse: 14% Refuse Description: Ends and skin"
Production quantity reduced by 14%
** near complete protein; lysine 0.88, meth+cys 1.39, tryptophan 2.19

Teff
a type of lovegrass: Eragrostis Teff
Lovegrass has small grains, and is not usually used for food, except for Teff.
USDA Nutrient data (SR24) used for: "Teff, uncooked"
Yield (2200 kg/ha) from:
WorldBank.org, 'Tef', Seyfu Ketema, Biodiversity Institute, Addis Abeba, Ethiopia;
"Landraces and current cultivars give low yield. At present the national average grain yield of tef is 910 kg/ha. Improved varieties of tef give a grain yield of 1700-2200 kg/ha on farmers' fields and 2200-2800 kg/ha on research managed large farms."
http://www.worldbank.org/html/cgiar/newsletter/Sept97/10tef.html
Yield reduced by 25%, as a rough estimate of percentage of hulls (cf. barley).
Teff is lacking in lysine, per:
Jansen, et al., 'Cereal Proteins, Amino Acid Composition and lysine Supplementation of Teff', J. Agric. Food Chem., 1962, 10 (1), pp 62-64; http://pubs.acs.org/doi/pdf/10.1021/jf60119a021
See also: USDA Nutrient data (SR24) used for: "Teff, uncooked"
* incomplete protein; lysine 0.55, meth+cys 2.00, tryptophan 1.49 (from my analysis of SR24 data).

Tomato PC
Yield (80,279 kg/ha) from FAOSTAT 2009 USA data.
2011 tomato yield in California was 107,064 kg/ha, converted from 47.76 short tons per acre:
USDA, ERS, "Vegetables and Pulses Outlook", VGS-350, June 28, p. 11;
http://www.ers.usda.gov/media/826842/vgs350.pdf
USDA Nutrient data (SR24) used for "Tomatoes, red, ripe, raw, year round average"
"Refuse: 9% Refuse Description: Core and stem ends"
Production quantity reduced by only 5%, because more of the plant can be used in PC
* incomplete protein; lysine 0.60, meth+cys 0.68, tryptophan 0.97, leucine 0.52, valine 0.64, isoleucine 0.82

Triticale
USDA Nutrient data (SR24) used for: "Triticale flour, whole-grain"
Days to maturity estimated from:
Government of Alberta, Canada; Agriculture and Rural Development, "Triticale Crop Production", Table 24. 'Spring Triticale Varieties';
http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/fcd10571
Yield (2479 kg/ha) from FAOSTAT 2009 Canada data (not much triticale grain is grown in the U.S.)
Yield reduced by 20% to account for hulls.
* incomplete protein; lysine 0.55, meth+cys 1.47, tryptophan 1.71.

Turnip greens
Yield (16800 kg/ha) from Oregon State University Commercial Vegetable Production Guide;
http://nwrec.hort.oregonstate.edu/turnipgr.html
USDA Nutrient data (SR24) used for: "Turnip greens, raw"
Refuse: 30% Root crown, tough stems and discarded leaves
Yield quantity reduced by 30% (to 70%).
*** complete protein; lysine 1.28, meth+cys 1.36, tryptophan 2.48.

Turnip roots
Yield (39,333) from: USDA ERS 2009 data: "Table45.xls World carrots & turnips: Yield per hectare, 1961-2009";
http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1577
USDA Nutrient data (SR24) used for: "Turnips, raw"
"Refuse: 19% Refuse Description: Parings"
* incomplete protein; lysine 0.78, meth+cys 0.71, tryptophan 1.43, leucine 0.67, phenyl+tyro 0.71.

Ulluco
Ullucus tuberosus, papalisa
Macronutrients: protein 1.5%, fat 0.07%, carbs 14% estimated from:
Lost Crops of the Incas, p. 109;
and
Kraljevic, "Andean grains and tubers: ancient crops for better livelihoods today", In: Hunger and Poverty: the role of biodiversity; p. 119;
http://www.unscn.org/layout/modules/resources/files/Hunger_and_poverty_The_role_of_biodiversity.pdf
Yield 7000 kg/ha and time to maturity estimated from:
Lost Crops of the Incas, p. 109:
"Yields averaged 5-9 tons per hectare under traditional conditions."
"Cultivars vary greatly in the time they require to reach maturity. The growing cycle may be as short as 5 months, but 6-8 months is more common; at high elevations (above 3,750 m) 9 months or more is the norm."
Essential amino acid data not found.
Fiber from: Felipe Artemio Surco Laos, "Caracterización de almidones aislados de tubérculos andinos: mashua (Tropaeolum tuberosum), oca (Oxalis tuberosa), olluco (Ullucus tuberosus) para su aplicación tecnológica", 2004;
http://www.cybertesis.edu.pe/sisbib/2004/surco_lf/html/sdx/surco_lf.html

Walnuts, English

USDA Nutrient data (SR24) used for: "Nuts, walnuts, English"
"Refuse: 55% Refuse Description: Shells"
Yield from:
Klonsky, "Economics of Farming Walnuts on Small Acreage";
http://agecon.ucdavis.edu/extension/presentations/files/klonsky/walnuts_on_small_acreage.pdf
* incomplete protein; lysine 0.55, meth+cys 1.17, tryptophan 1.59

Walnuts, black
USDA Nutrient data (SR24) used for: "Nuts, walnuts, black, dried"
"Refuse: 76% Refuse Description: Shells"
Yield estimated as average value (1.3 short tons) in:
Karen Klonsky, Economics of Walnut Establishment and Production, University of California Davis, Dept. of Agricultural and Resource Economics, citing NASS as source of data; converted to kg/ha;
http://agecon.ucdavis.edu/extension/presentations/files/klonsky/walnuts_lake_co.pdf
* incomplete protein; lysine 0.58, meth+cys 1.54, tryptophan 1.89

Watermelon
Yield (35,200 kg/ha) from FAOSTAT 2009 USA data.
USDA Nutrient data (SR24) used for "Watermelon, raw"
"Refuse: 48% Refuse Description: Rind, seeds, and cutting loss"
Production quantity reduced by 48%.
* incomplete protein; lysine 1.99, meth+cys 0.52, tryptophan 1.64, leucine 0.54, valine 0.82

Wheat
Yield (2989 kg/ha) from FAOSTAT 2009 USA data.
Yield reduced to account for losses in cleaning and hulling crop.
USDA Nutrient data (SR24) used for "Wheat flour, whole-grain"
* incomplete protein; lysine 0.54, meth+cys 1.54, tryptophan 2.21.

Wild rice
Yield estimated from:
California Wild Rice Advisory Board, 'Facts About California Wild Rice', 2009;
http://www.cawildrice.com/wild-rice-facts.php
and
Oelke, et al., Alternative Field Crops Manual, 'Wild Rice', 1997;
http://www.hort.purdue.edu/newcrop/afcm/wildrice.html
Yield reduced 20% based on estimate of weight lost to hulling by comparison with other grains.
Time to maturity estimated from:
Oelke, et al., Alternative Field Crops Manual, 'Wild Rice', 1997;
http://www.hort.purdue.edu/newcrop/afcm/wildrice.html
USDA Nutrient data (SR24) used for: "Wild rice, raw"
** near complete protein; lysine 0.84, meth+cys 1.66, tryptophan 1.74.

Winged bean seeds
Anti-nutritional factors in winged bean seeds per:
De Lumen, et al., "Tocopherols of winged bean (Psophocarpus tetragonolobus) oil",
http://pubs.acs.org/doi/abs/10.1021/jf00109a010

mean that this food should be studied further before being used as a staple food. Eating raw winged bean seeds in substantial quantity could be dangerous to the health of humans and domesticated animals.
Time to harvest estimated from source below (NRC, 1975), which states 40 additional days for mature seeds from mature pods, and time to harvest for mature pods.
Yield (at least seven reports of >2 t/ha) from:
National Research Council (U.S.). Panel on the Winged Bean, "The winged bean: a high-protein crop for the tropics : report", National Academies, 1975;
http://books.google.com/books?id=aT8rAAAAYAAJ
USDA Nutrient data (SR24) used for: "Winged beans, mature seeds, raw"
*** complete protein; lysine 1.41, meth+cys 1.22, tryptophan 3.67.
Fiber estimated from comparison with Soybeans, mature seeds, raw.

Winged bean seed oil
De Lumen, et al., "Tocopherols of winged bean (Psophocarpus tetragonolobus) oil",
http://pubs.acs.org/doi/abs/10.1021/jf00109a010
The oil needs further study as a possible source of dietary fat for humans.

Winged bean pods
Yield (9.16 t/ha) a 5-year average from:
Department of Agriculture, Government of Sri Lanka, "Winged Bean", Winged bean extent & production 5 year period, 1997 to 2001;
http://www.agridept.gov.lk/index.php/en/crop-recommendations/996
Time to harvest estimated from several sources.
USDA Nutrient data (SR24) used for: "Winged beans, immature seeds, raw"
"Refuse: 2% (Ends)"
Note that the USDA term 'immature seeds' is a reference to the immature seeds with the pods. It is the ends of the pods that are cut off as refuse (2%).
Data on essential amino acids not found.
Fiber estimated from comparison to: Peas, edible-podded, raw.

Winged bean tubers
Time to harvest (5 to 12 months) and yield (5.5 to 11.7 t/ha) from:
National Research Council (U.S.). Panel on the Winged Bean, "The winged bean: a high-protein crop for the tropics : report", National Academies, 1975;
http://books.google.com/books?id=aT8rAAAAYAAJ
USDA Nutrient data (SR24) used for: "Winged bean tuber, raw"
*** complete protein; lysine 1.00, leucine 1.00, meth+cys 1.17, tryptophan 3.10.
Fiber estimated as the average value of the range cited in: Kadam, et al., "Winged bean in human nutrition", CRC Critical Reviews in Food Science and Nutrition, Volume 21, Issue 1, 1984;
http://www.tandfonline.com/doi/abs/10.1080/10408398409527395

Winged bean leaves
Yield (8 t/ha) and time to harvest (60 days) from:
Leaf for Life, "Psophocarpus tetragonolobus - Winged bean, Goa bean, Four angled bean, Frijol alata", 2002;
http://www.leafforlife.org/PAGES/PSOPHOCA.HTM
USDA Nutrient data (SR24) used for: "Winged bean leaves, raw"
** near complete protein; lysine 0.76, meth+cys 0.95, tryptophan 2.83.

Fiber estimated by comparison with amaranth leaves.

Yacon
Polymnia sonchifolia
Yacon contains high levels of oligofructose (inulin), a form of sugar that is not metabolized readily by the human body.
Macronutrient data and time to maturity estimated by averaging the range of numbers given in:
Lost Crops of the Incas, p. 119.
Protein: 1.3 g (0.4 to 2.2 g), Fat: 0.85 (0.4 to 1.3 g).
Carb content and yield (54 t/ha) from: Ohyama, et al., "Composition of storage carbohydrate in tubers of yacon (Polymnia sonchifolia)", Soil Science and Plant Nutrition, 1990, 36:1, 167-171;
http://www.tandfonline.com/doi/pdf/10.1080/00380768.1990.10415724
Carb content is counted as fructose, glucose, and sucrose (8%), since inulin is not digestible, plus other fiber content (3.6%), with the latter estimated as the midpoint in the range of values from:
Hermann, et al., "Compositional Diversity of the Yacon Storage Root";
http://cipotato.org/library/pdfdocs/RTA58114.pdf

Yams
genus Dioscorea, various species
Yield and Time to maturity from: FARMER'S BOOKSHELF, An information system of tropical crops in Hawaii, Department of Tropical Plant & Soil Sciences, University of Hawaii at Manoa;
http://www.ctahr.hawaii.edu/fb/yam/yam.htm
Compared to: Linus Opara, "Yams: Post-Harvest Operation", Massey University, New Zealand;
http://www.fao.org/fileadmin/user_upload/inpho/docs/Post_Harvest_Compendium_-_Yams.pdf
USDA Nutrient data (SR24) used for: "Yam, raw"
** near complete protein; lysine 0.76, meth+cys 1.05, tryptophan 1.12.

Yautia
Xanthosoma sagittifolium, new cocoyam
USDA Nutrient data (SR24) used for: "Yautia (tannier), raw"
"Refuse: 14% Refuse Description: Peel"
Yield from FAOSTAT 2009 world data: 7951 kg/ha
Time to harvest (9 to 11 months) from:
Neglected Crops: 1492 from a Different Perspective. 1994. J.E. Hernándo Bermejo and J. León (eds.). Plant Production and Protection Series No. 26. FAO, Rome, Italy. p. 253-258;
http://www.hort.purdue.edu/newcrop/1492/tannia.html
No essential amino acid information found.