Sources of enzymes

Biologically active enzymes may be extracted from any living organism. A very wide range of sources are used for commercial enzyme production from *Actinoplanes* to *Zymomonas*, from spinach to snake venom. Of the hundred or so enzymes being used industrially, over a half are from fungi and yeast and over a third are from bacteria with the remainder divided between animal (8%) and plant (4%) sources (see Table). A very much larger number of enzymes find use in chemical analysis and clinical diagnosis. Non-microbial sources provide a larger proportion of these, at the present time. Microbes are preferred to plants and animals as sources of enzymes because:

1. they are generally cheaper to produce.
2. their enzyme contents are more predictable and controllable,
3. reliable supplies of raw material of constant composition are more easily arranged, and
4. plant and animal tissues contain more potentially harmful materials than microbes, including phenolic compounds (from plants), endogenous enzyme inhibitors and proteases.

Attempts are being made to overcome some of these difficulties by the use of animal and plant cell culture.

In practice, the great majority of microbial enzymes come from a very limited number of genera, of which *Aspergillus* species, *Bacillus* species and *Kluyveromyces* (also called *Saccharomyces*) species predominate. Most of the strains used have either been employed by the food industry for many years or have been derived from such strains by mutation and selection. There are very few examples of the industrial use of enzymes having been developed for one task. Shining examples of such developments are the production of high fructose syrup using glucose isomerase and the use of pullulanase in starch hydrolysis.

Producers of industrial enzymes and their customers will share the common aims of economy, effectiveness and safety. They will wish to have high-yielding strains of microbes which make the enzyme constitutively and secrete it into their growth medium (extracellular enzymes). If the enzyme is not produced constitutively, induction must be rapid and inexpensive. Producers will aim to use strains of microbe that are known to be generally safe. Users will pay little regard to the way in which the enzyme is produced but will insist on having preparations that have a known activity and keep that activity for extended periods, stored at room temperature or with routine refrigeration. They will pay little attention to the purity of the enzyme preparation provided that it does not contain materials (enzymes or not) that interfere with their process. Both producers and users will wish to have the enzymes in forms that present minimal hazard to those handling them or consuming their product.

The development of commercial enzymes is a specialised business which is usually undertaken by a handful of companies which have high skills in

1. screening for new and improved enzymes,
2. fermentation for enzyme production,
3. large scale enzyme purifications,
4. formulation of enzymes for sale,
5. customer liaison, and
6. dealing with the regulatory authorities.

Table : Some important industrial enzymes and their sources.

Enzyme[a]	EC number[b]	Source	Intra/extra -cellular[c]	Scale of production[d]	Industrial use
Animal enzymes					
Catalase	1.11.1.6	Liver	I	-	Food
Chymotrypsin	3.4.21.1	Pancreas	E	-	Leather
Lipase[e]	3.1.1.3	Pancreas	E	-	Food
Rennet[f]	3.4.23.4	Abomasum	E	+	Cheese
Trypsin	3.4.21.4	Pancreas	E	-	Leather
Plant enzymes					
Actinidin	3.4.22.14	Kiwi fruit	E	-	Food
a-Amylase	3.2.1.1	Malted barley	E	+++	Brewing
b-Amylase	3.2.1.2	Malted barley	E	+++	Brewing
Bromelain	3.4.22.4	Pineapple latex	E	-	Brewing
b-Glucanase[g]	3.2.1.6	Malted barley	E	++	Brewing
Ficin	3.4.22.3	Fig latex	E	-	Food
Lipoxygenase	1.13.11.12	Soybeans	I	-	Food
Papain	3.4.22.2	Pawpaw latex	E	++	Meat
Bacterial enzymes					
a-Amylase	3.2.1.1	*Bacillus*	E	+++	Starch
b-Amylase	3.2.1.2	*Bacillus*	E	+	Starch
Asparaginase	3.5.1.1	*Escherichia coli*	I	-	Health
Glucose isomerase[h]	5.3.1.5	*Bacillus*	I	++	Fructose syrup
Penicillin amidase	3.5.1.11	*Bacillus*	I	-	Pharmaceutical
Protease[i]	3.4.21.14	*Bacillus*	E	+++	Detergent
Pullulanase[j]	3.2.1.41	*Klebsiella*	E	-	Starch
Fungal enzymes					
a-Amylase	3.2.1.1	*Aspergillus*	E	++	Baking
Aminoacylase	3.5.1.14	*Aspergillus*	I	-	Pharmaceutical
Glucoamylase[k]	3.2.1.3	*Aspergillus*	E	+++	Starch
Catalase	1.11.1.6	*Aspergillus*	I	-	Food
Cellulase	3.2.1.4	*Trichoderma*	E	-	Waste
Dextranase	3.2.1.11	*Penicillium*	E	-	Food
Glucose oxidase	1.1.3.4	*Aspergillus*	I	-	Food
Lactase[l]	3.2.1.23	*Aspergillus*	E	-	Dairy
Lipase[e]	3.1.1.3	*Rhizopus*	E	-	Food
Rennet[m]	3.4.23.6	*Mucor miehei*	E	++	Cheese
Pectinase[n]	3.2.1.15	*Aspergillus*	E	++	Drinks
Pectin lyase	4.2.2.10	*Aspergillus*	E	-	Drinks
Protease[m]	3.4.23.6	*Aspergillus*	E	+	Baking
Raffinase[o]	3.2.1.22	*Mortierella*	I	-	Food
Yeast enzymes					
Invertase[p]	3.2.1.26	*Saccharomyces*	I/E	-	Confectionery
Lactase[l]	3.2.1.23	*Kluyveromyces*	I/E	-	Dairy
Lipase[e]	3.1.1.3	*Candida*	E	-	Food
Raffinase[o]	3.2.1.22	*Saccharomyces*	I	-	Food

a The names in common usage are given. As most industrial enzymes consist of mixtures of enzymes, these names may vary from the recommended names of their principal component. Where appropriate, the recommended names of this principal component is given below.
b The EC number of the principal component.
c I - intracellular enzyme; E - extracellular enzyme.
d +++ > 100 ton year-1; ++ > 10 ton year-1; + > 1 ton year-1; - < 1 ton year-1.
e triacylglycerol lipase;
f chymosin;
g Endo-1,3(4)-beta-glucanase;
h xylose isomerase;
i subtilisin;
j alpha-dextrin endo-1,6-alpha-glucosidase;
k glucan 1,4-alpha-glucosidase;
l beta-galactosidase;
m microbial aspartic proteinase;
n polygalacturonase;
o alpha-galactosidase;
p beta-fructofuranosidase.