TABLE 9.3 Some Traditional Food Fermentations

Product	Primary genus	Common substrate	Thermal processing		Initial moisture (%)	Incubation		Further processing
			Temp. (°C)	Time (min)		Time (h)	Temp. (°C)	
Soy sauce	*Aspergillus*	Soybean, wheat	110	30	45	72	30	Yes
Miso	*Aspergillus*	Rice, soybean	100	40	35	44	30	Yes
Tempeh	*Rhizopus*	Soybean	100	30	40	22	32	No
Hamanatto	*Aspergillus*	Soybean, wheat				36		Yes
Sufu	*Actinomucor*	Tofu	100	10	74		15	Yes

With permission, from R. E. Midgett, in A. L. Demain and N. A. Solomon, eds., *Manual of Industrial Microbiology and Biotechnology*, ACS Publications, Washington, D.C., 1986.

The major industrial use of the koji process is for the production of enzymes by fungal species. Fungal amylases are produced by SSF of wheat bran by *A. oryzae* in a rotating-drum fermenter. Wheat bran is pretreated with formaldehyde, and the initial pH of the bran is adjusted to pH = 3.5 to 4.0 to reduce the chance of contamination. Usually, perforated pans, rotating drums, or packed beds with air ventilation are used. A typical rotary-drum type of koji fermenter is depicted in Fig. 9.16. Enzymes other than amylases, such as cellulase, pectinase, protease, and lipases, can also be produced by koji fermentations. *Trichoderma viride* species have been used for the production of cellulases from wheat bran in a rotary-tray fermenter.

Some secondary metabolites, such as antibacterial agents, are produced by *Rhizopus* and *Actinomucor* species in some koji processes. Certain mycotoxins, such as aflatoxins, were produced by SSF of rice (40% moisture) by *A. parasiticus*. Ochratoxins were also produced by *Aspergillus* species on wheat in a rotary-drum koji fermenter. Microbial degradation of lignocellulosics can also be accomplished by solid-state fermentations for waste-treatment purposes or in biopulping of wood chips for use in paper manufacture. Spores from some molds have found use as insecticides. Proper spore formation is difficult to obtain in submerged culture, and SSF must be used.

Major process variables in SSF systems are moisture content (water activity), inoculum density, temperature, pH, particle size, and aeration/agitation. Optimization of these parameters to maximize product yield and rate of product formation is the key in SSF systems and depends on the substrate and organism used. Most natural substrates (e.g., grains) require pretreatment to make the physical structure of substrates more susceptible to mycelial penetration and utilization. Solid substrates are usually treated with antimicrobial agents, such as formaldehyde, and are steamed in an autoclave. Nutrient media addition, pH adjustment, and the adjustment of moisture level are realized before inoculation of the fermentation mash. Koji fermentations are usually realized in a controlled-humidity air environment with air ventilation and agitation. Many solid-state mycelial fermentations are shear sensitive due to disruption of the mycelia at high