Biotechnology and Food Production

One of the biggest problems facing the world today is population growth, especially in developing nations. Conventional agriculture may not be able to provide sufficient supply of food and, in particular, protein. However, productivity is increasing throughout the world in all branches of agriculture. Biotechnological innovations will accelerate this trend.

Genetically engineered farm animals:

The pituitary gland of animals secretes growth hormones which can have major influence on how the animal grows and, in lactating animals, on milk production. In the 1980s the gene responsible for bovine growth hormone (somatotropin) production (BST) was successfully isolated and transferred into bacterial cells to produce large quantities of BST (Figure1). When cows were injected with about 30 mg BST there was significant increase in milk production (10–30%).

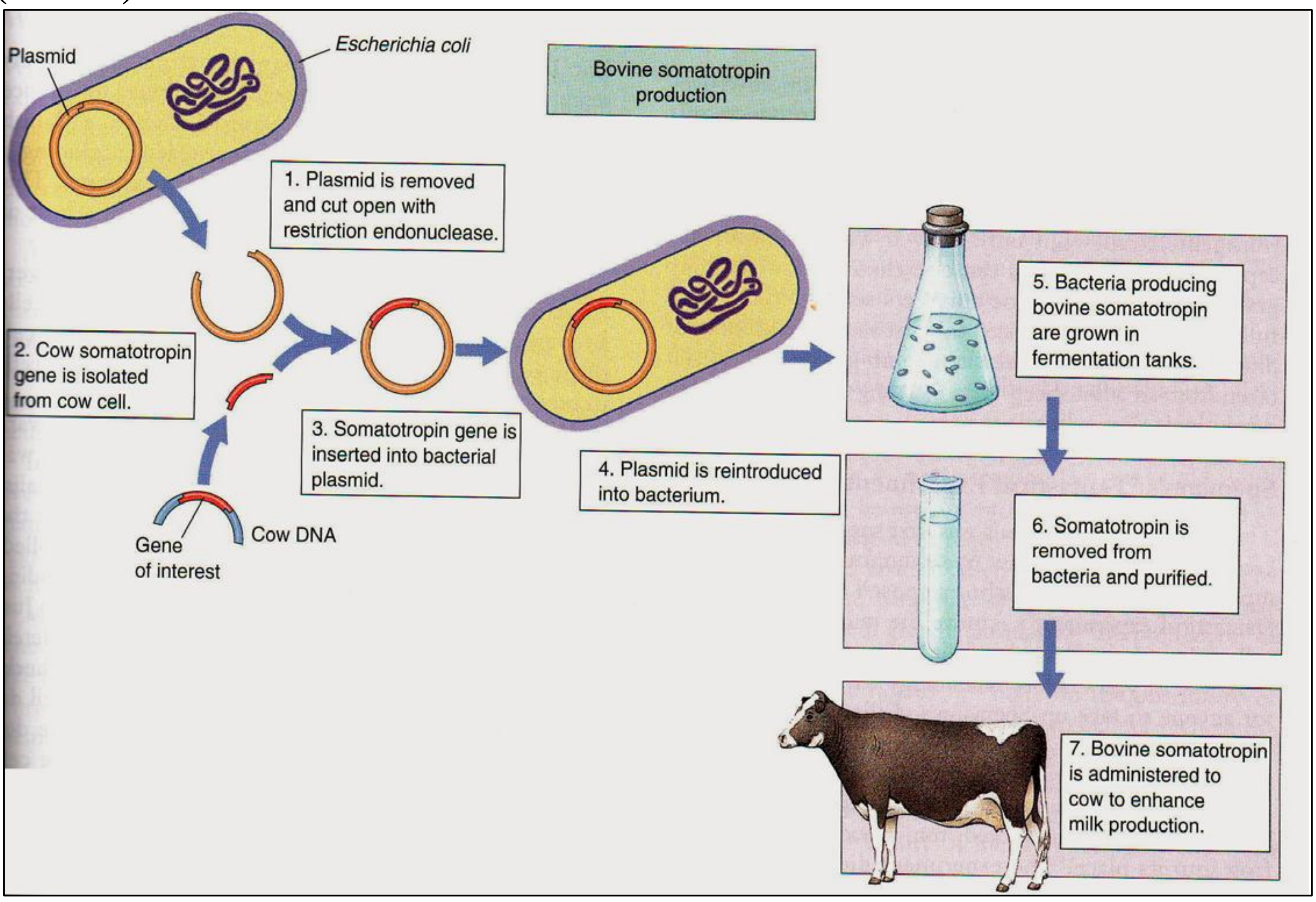

Fig1 Recombinant Bovine Somatotropin (rBST)

Artificial BST lacks extra amino acids, if injected into cows; they will require extra food to cope with the increased milk production. There are some serious side effects of injected BST in cows: Prolonged use of BST lowers the cows immune system BST - they have a 78% higher chance of getting sick; they easily get more infections, so far there are no other observable side-effects like birth defects, or changes in behavior.

BST ingested in milk or meat has no effect on humans, because it is a protein and is digested in stomach. Although BST is functional, harmless and approved by US government,

• BST has met with some public resistance
• Some people mistrust any foods produced via genetic engineering
• A generalized fear of gene technology!?

The tick resistant sheep (as the thick sucks blood, the modified blood plasma containing chitinase is able to break down the ticks chitin shell).

Single cell protein (SCP)

The use of microbes as protein producers has also gained wide experimental success. This field of study has become known as single cell protein production (SCP) and reflects the fact that most microorganisms used as producers grow as single (bacteria, yeast) or filamentous fungi and algae individuals rather than as complex multicellular organisms such as plants or animals.

Applications of SCP:

1.Cheese industry: the huge amounts of whey that otherwise are dumped as sewage (can contaminate drinking water), are further processed by GM-yeast that use up the remnant lactose, proteins, and vitamins. Nowadays, the resulting product is used as food supplements for cattle.

2.Sugar industry: molasses the end product in sugar refinery used to be fermented for rum-making, nowadays it is further processed by GM-bacteria to obtain a cattle food supplement.

3.Sulphite liquor: a waste product of paper mills contains low levels of sugar; feeding GM-fungi with this low-level nutrient, yields bio-degradable waste while generating substantial amount of heat that can be further used.

4.Natural gas with the help of GM-methanous bacteria, this gas can be converted to long-chain hydrocarbons; i.e. liquid fuel;

5.Alkanes: straight chained alkanes are waxy oil; until the dawn of biotechnology there was very little use for them; the biotech industry came up with a GM-modified bacteria that converts alkanes into primary substrates for the synthetic protein production of another GM-branch.

The advantages of using microbes for SCP production

1.Microorganisms can grow at remarkably rapid rates under optimum conditions; some microbes can double their mass every 0.5–1 hour.

2.Microorganisms are more easily modified genetically than plants and animals; they are more amenable to large-scale screening programs to select for higher growth rate and can be more easily subjected to gene transfer technology.

3.Microorganisms have relatively high protein content and the nutritional value of the protein is good.

4.Microorganisms can be grown in vast numbers in relatively small continuous-fermentation processes, using relatively small land area, and are also independent of climate.

5.Microorganisms can grow on a wide range of raw materials, in particular low-value wastes, and some can also use plant-derived cellulose.

Disadvantages of SCP:

1.High percentage of contaminants that can be found in the extract (traces of sewage, excrements, waste, etc); purification at this stage is rather expensive and no one can guarantee a 100% pure product.

2.Prokaryotes contain a large amount of nucleic acids in order to maintain exponential growth; compared to other foodstuffs, the SCP's nucleic and amino acid content is around 15%, while those in conventional food is only around 4%; consequently, relying on SCP's only would cause serious health problems, like kidney stones, diarrhea, vomiting, etc. SCP's can therefore, only be utilized as food supplements for humans and animals.

3.Food-chains are usually less efficient (energy losses) - roughly 10-30% is obtained at the end; this is also reflected in the low nutrient level and higher financial costs.

Biotechnology in plant sciences

Genetic Engineering has allowed us to produce genetically modified plants with diversified properties such as resistance against **pest, drought, and abiotic stress**. These are few selected examples of advancement in the plant sciences due to technological contributions of biotechnology. Ti Plasmid a successful vector for plant cells, isolated from tumor-inducing bacteria of plant able to integrate in the DNA of infected plant cells (Figure 2). With the Ti Plasmid, we can make transgenic crop with desirable traits (as above, see below).

Insect resistant plants:

A genetically altered crop is produced to develop resistant against insects. One of the approaches is to genetically modify the plant which will express a toxin to kill the insects but will be safe for human consumption. *Bacillus thuringiensis* (Bt) is a bacteria which secretes a insecticidal toxin. Spraying Bt toxin was in circulation to control the insect population. With the use of genetic engineering transgenic plants are produced which express Bt toxin in their somatic cells. When insect feeds on the plant, toxin reach to the stomach and causes internal bleeding to kill the insect.

Herbicide resistant plants:

Weeds grow very fast and they compete for nutrients with the crop plant. Chemical herbicides are used in the agriculture to eradicate weeds from the fields. If weeds need to be removed from the crop, herbicide should do little or no effect on the crop plants. Herbicides are either selective towards a class of plant or non-selective to kill all plants they applied to and used more often to kill all vegetation. Glyphosate is one of the first herbicide designed to kill weeds. It interferes biosynthesis of aromatic amino acid tyrosine, phenylalanine and tryptophan by inhibiting enzyme 5-enolpyruvylshikimate-3-phosphate synthase (EPSP). The enzyme catalyzes the conversion of the shikimate-3-phosphate to the 5-enolpyruvylshikimate-3-phosphate. The treated plant cannot be able to produce these amino acids as well as protein needed and dies. There are two approaches, adopted to develop herbicide resistant in crop plant. (1) The genetically modified crop plant is designed with an alternate pathway to supply the aromatic amino acid to compensate the inhibition of EPSP. (2) Few bacterial strains use an alternate form of EPSP that is resistant to the glyphosate inhibition. The modified version of EPSP gene was isolated from the *Agrobacterium strain* CP4 and cloned into the crop plant to provide herbicide resistant. So far the crop plants commercially available with herbicide resistant are soy, maize, sorghum, canola and cotton.

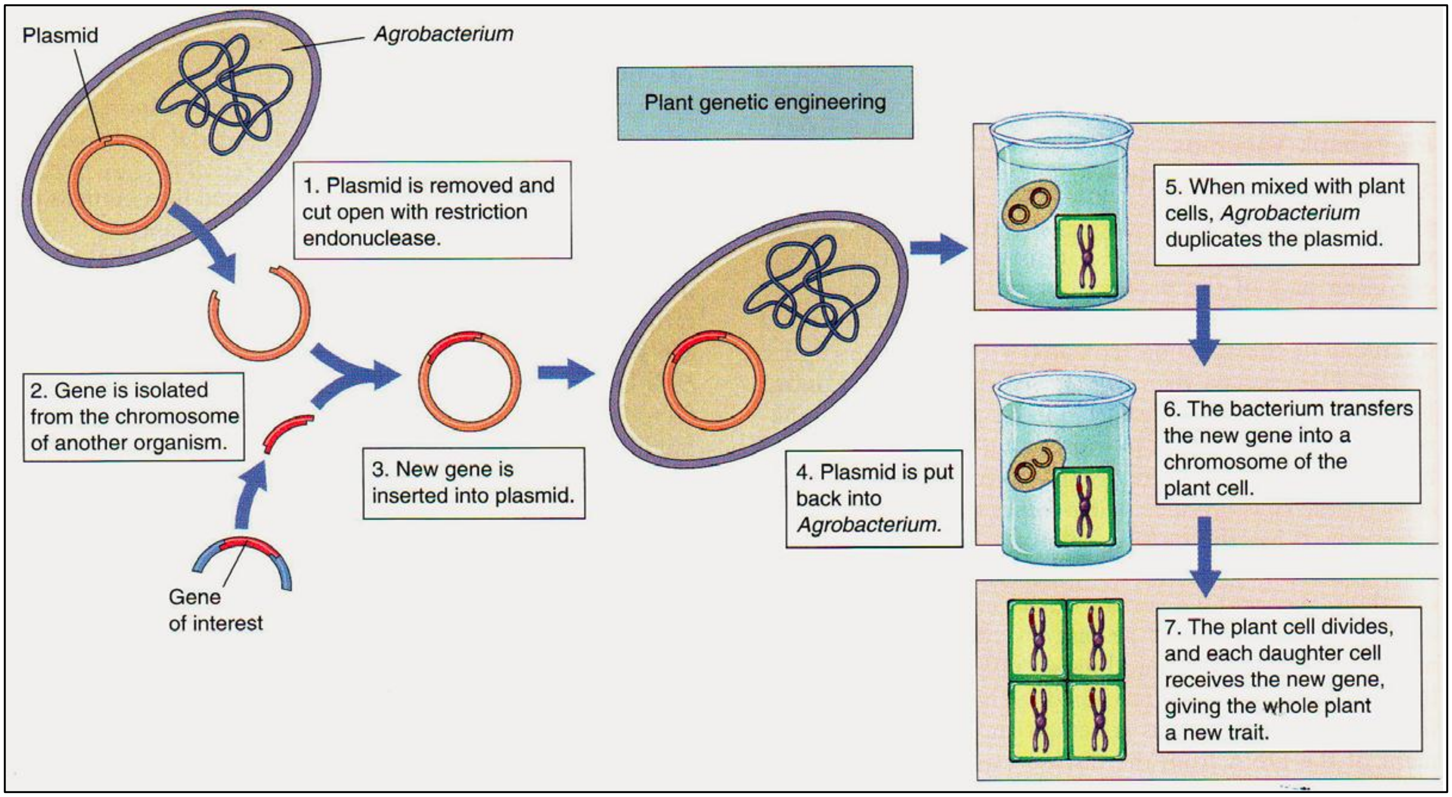

Fig 2 Transformation using *Agrobacterium tumefaciens* is the most common plant engineering method

Disease resistant plants:

Plants are under continuous exposure to the pathogenic organism and the environmental conditions. Pathogenic organisms (bacteria, fungi, mycoplasma, and virus) attack on plants to gain nutrients for their growth and disturb its metabolism to exhibit pathological symptoms.

Plants have R gene (resistance gene) which produces R protein and these virulence factors allow acquiring resistance to combat pathogens. Every R gene recognizes pathogen protein in a receptor-ligand fusion and as a result R gene product provides resistance against a particular pathogen or a family of related pathogens. R gene has the ability to modify its product to acquire resistance against new species of pathogen. A good example includes barley MLO against powdery mildew, wheat Lr34 against leaf rust, and wheat Yr36 against stripe rust.

Abiotic stress resistant plants:

Transgenic plants provide resistance against salt, UV radiation, drought, etc.

Improving nutritional values: ex. transgenic rice

Problems of natural rice are too little iron, vitamin A and sulfur. Sulfur is required for iron uptake and absorption, rice has very little of it. Transgenic rice offers the promise of improving the diets of people in rice-consuming countries, where iron and vitamin A deficiencies are a serious problem (Figure 3).

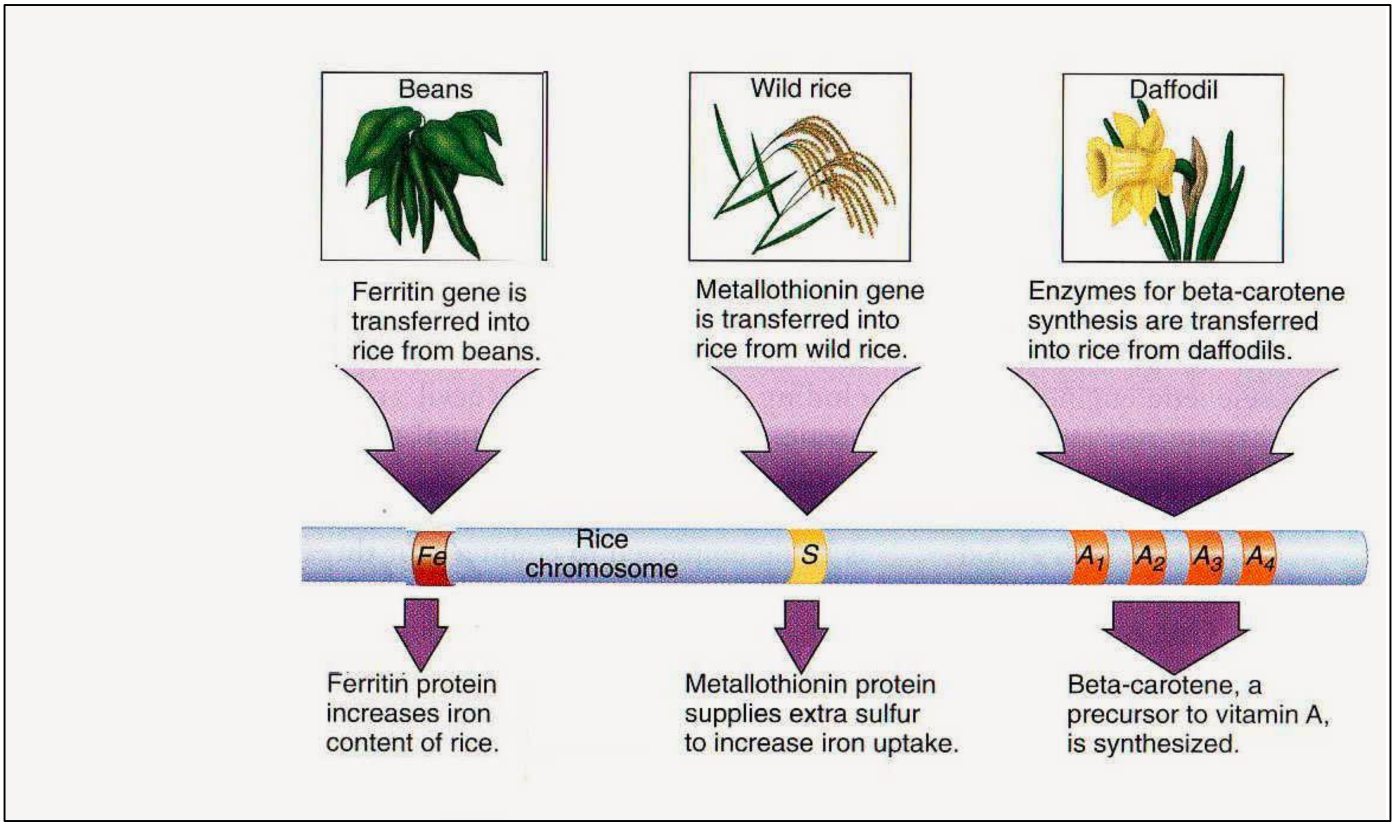

Fig3 Genes transfer to rice chromosome from other plants

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