

## Production of dextrans and their applications in human health and nutrition– Review

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### Abstract:

*An increasing consumer trend towards healthy and additive-free food has made dextran from food grade lactic acid bacteria (LAB) an attractive solution. Dextrans are homopolysaccharides of D-glucose produced by extracellular dextransucrase released from LAB of the genera, viz., Leuconostoc, Lactobacillus, Streptococcus, Weissella, and Pediococcus. Dextrans have been known for their viscosifying,*

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*emulsifying, texturizing, stabilizing attributes in food applications. Dextran has the potential to be recruited as a novel ingredient replacing the commercial hydrocolloids in bakery and other food industries. Prebiotic oligosaccharide production by hydrolysis of dextran is a rather new field, garnering research and industrial attention. The applications, available sources, preparation, and characterization of dextran and problems associated with its use have been discussed. This review also highlights the key developments in recent times and discusses the importance of bio-prospecting novel dextran- producing isolates from biodiversity.*

**Key words:** Dextran, *Leuconostocmesenteroides*, Sucrose, Food industry, Dextransucrase

## INTRODUCTION

Dextran is the collective term given to a group of bacterial polyglucan composed of chains of D – glucose units connected by alpha – (1 -6) linkages. These polysaccharides are synthesized by a number of bacterial species. The synthesis occurs extracellularly and is catalyzed by a species specific enzyme, dextransucrase. Dextran is produced at the industrial level by the fermentation of sucrose rich media. Yield of the product depends on various factors like temperature, pH and nitrogen source. Dextran is commercially available and it is used as drugs, especially as blood plasma volume expander. It has found industrial application in food, pharmaceutical and chemical industries as adjuvant, emulsifier, carrier and stabilizer. In food industry dextran is currently used as thickener for jam and ice-cream. It prevents crystallization of sugar, improves moisture retention and maintains flavor and appearance of various food items.

Dextran is a complex, branched polysaccharide made of many glucose molecules composed of chains of varying length (from 10 to 150 kilodaltons). The native dextran straight chain

consists of alpha – 1,6glycosidic linkages between glucose molecules; while branches begin from alpha-1,4 linkage (alpha-1,2 and alpha-1,3 linkages as well) The polyglucans are synthesized from sucrose by many species of the genera *Leuconostoc*, *Lactobacillus* and *Streptococcus*. **Hucker and Pederson** (1930) was the first who reported the production of dextran from sucrose by strains of *Leuconostoc* species. **Jeans et al** (1954) reported the formation of dextran from different strains of bacteria that were primarily *Leuconostoc* strains. Species of bacteria from other genera have been also found to produce dextran. Soluble and insoluble dextran are produced and molecular weights range from  $1.5 \times 10^4$  to  $2 \times 10^7$  and higher.

Dextran is the generic name of a large family of microbial polysaccharides that are assembled or polymerized outside the cell by enzymes called dextran sucrases. This class of polysaccharides is composed of building blocks (monomers) of the simple sugar glucose and is stored as fuel in yeasts and bacteria. Dextran polymers have a number of medical applications. Dextrans have been used for wound coverings, in surgical sutures, as blood volume expanders, to improve blood flow in capillaries in the treatment of vascular occlusion, and in the treatment of iron deficiency anemia in both humans and animals. Dextran-hemoglobin compounds may be used as blood substitutes that have oxygen delivery potential and can also function as plasma expanders. The progressively increasing demand of natural polymers for various industrial applications has led to the exploration of microbial exopolysaccharide (EPS) in recent years. Among several EPS, dextran has gained worldwide recognition due to its biodegradability and biocompatibility properties (Patel et al. 2010; Amanet al. 2012; Varshosaz 2012).

## CLASSIFICATION AND CHEMICAL STRUCTURE OF DEXTRAN

Hehre in 1941 reported the first cell-free synthesis of dextran using sucrose as the substrate from enzyme dextransucrase. Dextransucrase (sucrose: 1,6-  $\alpha$ -D-glucan 6-  $\alpha$ -glucosyltransferase) is the key enzyme that catalyzes the synthesis of dextran from sucrose. Dextrans generally vary in their molecular weight, spatial arrangement, type and degree of branching, and length of branched chains, depending on the source of strains and also on the cultivation conditions. A survey of dextrans from 96 strains (*Leuconostocmesenteroides*) demonstrated that the amount of  $\alpha$ -(1  $\rightarrow$  6) linkages in a specific dextran can vary from 50 % to 97 % of the total glycosidic linkages (Jeanes et al. 1954).

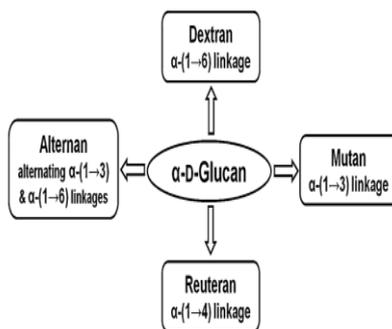


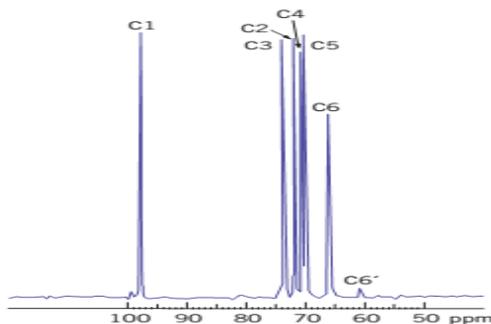
Fig. 1 Classification of  $\alpha$ -D-glucan depending upon the type of linkages

Dextrans are extracellular bacterial with a linear backbone of  $\alpha$ -linked D-glucofuranosyl repeating units. Dextrans belong to  $\alpha$ -D-glucans containing  $\alpha$ -(1  $\rightarrow$  6) linkage in the main chain and variable amounts of  $\alpha$ -(1  $\rightarrow$  2)-,  $\alpha$ -(1  $\rightarrow$  3)-, or  $\alpha$ -(1  $\rightarrow$  4)-branched linkages. There are four distinct types of  $\alpha$ -D-glucan produced by LAB (Fig. 1): (i) mutan contains a majority of  $\alpha$ -(1  $\rightarrow$  2) linkages in main chain and is produced by *Streptococcus* species; (ii) alternan containing alternating  $\alpha$ -(1  $\rightarrow$  3) and  $\alpha$ -(1

→6) linkages, reported only in *L. mesenteroides*; (iii) reuteran containing  $\alpha$ -(1 →4) linkages found only in *Lactobacillus reuteri* (Monchois et al. 1999; van Leeuwen et al. 2008); and (iv) dextran containing  $\alpha$ -(1→6) linkages in main chain and  $\alpha$ -(1 → 2)-,  $\alpha$ -(1 → 3)-, or  $\alpha$ -(1 → 4)-branched linkages (Jeanes et al. 1954; Naessens et al. 2005; Kothari and Goyal 2013).

**Table 1. Dependence of degree of branching on molecular weight.**

Dextran	Branching (%)
Native dextran	4.6
Dextran 80	3.8
Dextran 10	3.0



**Fig 2. <sup>13</sup>C-NMR spectrum of native dextran from *Leuconostocmesenteroides* B-512(F) in D<sub>2</sub>O.**

Although the values given in **Table 1** are somewhat lower than those generally accepted now for B-512(F), they provide a useful relative comparison. The rationale for this decrease is based on the greater liability to acid of a(13) linkages compared with a(16) linkages . Using less sensitive techniques, Bremner) did not find any difference in the branching between native dextran and dextran, MW 3 000. The <sup>1</sup>H- and <sup>13</sup>C-NMR spectra afford compelling evidence for the main structural features of dextran. The <sup>13</sup>C-NMR spectrum for native dextran NRRL B 512(F) is shown in Figure 1 and the individual assignments are shown in **Table 2**.

**Table 2.**<sup>13</sup>C and <sup>1</sup>H chemical shifts for dextran B-512(F)

	<sup>13</sup> C (ppm)	<sup>1</sup> H (ppm)
C1-H	97.8	4.99
C2-H	71.5	3.6
C3-H	73.5	3.76
C4-H	70.0	3.52
C5-H	70.3	3.88-4.04
C6-H	66.1	3.81-3.86
C1-H	61.0	-----

### Sources of Dextran

Dextran occurs naturally in small amounts in foods, such as refined crystalline sugar, maple syrup, sauerkraut juice, and honey, and also as a component of dental plaque. Dextran is synthesized by the action of bacterial enzyme, dextransucrase, on sucrose. Dextransucrase is the sole industrial enzyme used in the commercial production of dextran and is produced by LAB of genera, viz., *Leuconostoc*, *Streptococcus*, *Lactobacillus*, *Pediococcus*, and *Weissella*. The structure of each type of dextran depends on the microbial strain and hence on the specific dextransucrase. To date, commercial dextran is produced from *Leuconostocmesenteroides* NRRL B-512F and serves as a model in studying the structure of dextran and the mechanism of its biosynthesis by dextransucrase (Robyt et al. 2008; Siddiqui et al. 2014).

The amount of dextran produced however is practically insufficient to meet the dextran requirements of the various industries; hence, there is the need for the isolation and characterization of hyper dextran-producing LAB. Several examples of dextran with their linkage pattern from LAB isolated from various food sources are mentioned in **Table 3**.

**Table 3 Dextrans with their linkage pattern from different LAB isolated from various food sources**

Microorganism	Source	Linkage	References
<i>Leuconostoc mesenteroides</i> CMG713	Grape	$\alpha$ -(1 → 6) linkages only	Sarwat et al. (2008)
<i>Leuconostoc mesenteroides</i> AA1	Fermented cabbage	$\alpha$ -(1 → 6) linkages only	Aman et al. (2012)
<i>Lactobacillus satsumensis</i> NRRL B-59839	Water kefir grains	44 % $\alpha$ -(1 → 3) and 37 % $\alpha$ -(1 → 6)	Cote et al. (2012)
<i>Lactobacillus plantarum</i> DM	Marcha, fermented beverage	86.5 % $\alpha$ -(1 → 6) and 13.5 % $\alpha$ -(1 → 3)	Das and Goyal (2014)
<i>Pediococcus pentosaceus</i> CRAG3	Fermented cucumber	75 % $\alpha$ -(1 → 6) and 25 % $\alpha$ -(1 → 3)	Shukla and Goyal(2013)
<i>Weissellacibaria</i> CMGDEX3	Cabbage	96.6 % $\alpha$ -(1 → 6) and 3.4 % $\alpha$ -(1 → 3)	Ahmed et al. (2012)
<i>Weissellaconfusa</i> Cab3	Fermented Cabbage	97 % $\alpha$ -(1 → 6) and 3 % $\alpha$ -(1 → 3)	Shukla et al. (2014)
<i>Weissellacibaria</i> JAG8	Apple peel	93 % $\alpha$ -(1 → 6) and 7 % $\alpha$ -(1 → 3)	Rao and Goyal(2013)

## Dextranucrase

Dextranucrases (EC .2.4.1.5) are the sole industrial enzymes used in the commercial production of dextran (Parlak et al. 2013). Dextranucrase is classified in the family of glucanucrase, and most of the enzymes classified in this family use sucrose as the D-glucopyranosyl donor to synthesize  $\alpha$ -D-glucans of high molecular mass with the concomitant release of D-fructose. They are also referred to as glucosyltransferases (GTF) because they synthesize  $\alpha$ -glucan polymers using the glucose unit of sucrose (Leemhuis et al. 2013).

Four distinct types of GH70 glucanucrases have been identified based on the polysaccharides produced by them (Andre et al. 2010).

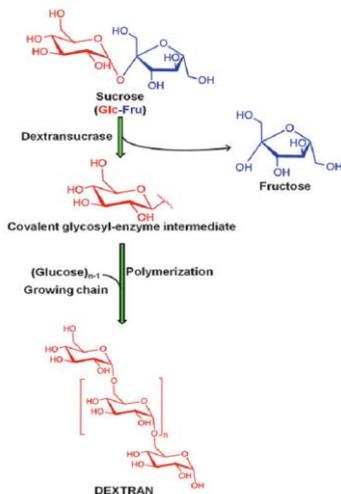
- Dextranase (E.C. 2.4.1.5): dextran, containing above 50 %  $\alpha$ -(1  $\rightarrow$  6) linkages
- Mutanase (E.C. 2.4.1.5): mutan, containing above 50 %  $\alpha$ -(1  $\rightarrow$  3) linkages
- Reuteranase (E.C. 2.4.1.5): reuteran, containing above 50 %  $\alpha$ -(1  $\rightarrow$  4) linkages
- Alternanase (E.C. 2.4.1.140): alternan, containing alternating  $\alpha$ -(1  $\rightarrow$  3) and  $\alpha$ -(1  $\rightarrow$  6)

### **Dextranase production and purification**

A loop of *W. cibaria* JAG8 maintained in a modified MRS agar medium as a stab culture was inoculated in 5 ml liquid modified MRS medium (Goyal & Katiyar, 1996), and grown at 24 C for 12 h. One percent of above grown culture was inoculated in 100 mL of the enzyme production medium as described by Tsuchiya et al. (1952) and incubated at 24 C for 12 h. The broth was centrifuged at 10 500g at 4 C for 10 min and cell free supernatant containing enzyme was purified by adding pre-chilled 33% (v/v) PEG-400 followed by incubation at 4 C for 12 h as reported earlier by Rao & Goyal (2013). The mixture was centrifuged at 17 200g at 4 C for 40 min and the enzyme pellet was dissolved in ice cold 20 mM sodium acetate buffer, pH 5.4 and dialysed against the same buffer using 14 kDa cutoff membrane and subsequently used for dextran synthesis.

The enzyme dextranase synthesizes dextran from sucrose with concomitant release of fructose by double-displacement mechanism (**Fig. 3**). In the first stage of double-displacement reaction,  $\alpha$  -(1  $\rightarrow$  2) glycosidic linkage of sucrose is cleaved with the release of fructose, and a glucosyl enzyme intermediate is formed , in which the glucosyl unit is covalently attached to the catalytic nucleophile via a  $\beta$  -glycosidic linkage . In the second stage of reaction, the covalently bound glucosyl moiety is transferred to the accepting nonreducing end of sugar

of a growing glucan chain, with reformation of the  $\alpha$ -glycosidic bond (Leemhuis et al. 2013).



**Fig. 3 Double-displacement mechanism of dextranase reaction (Adapted from Leemhuis et al. 2013)**

### **Preparation of Dextran**

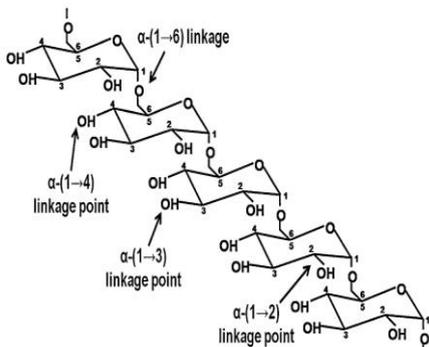
Dextran is produced commercially by cultivating *L. mesenteroides* strains in situ in growth medium supplemented with sucrose and in vitro by using purified dextranase with sucrose as a substrate (Leemhuis et al. 2013). The dextran of desired molecular weight can be achieved by the direct enzymatic synthesis using purified dextranase, which allows more control over the reaction conditions as compared with the fermentative synthesis (Falconer et al. 2011). The production of dextran by dextranase from LAB is affected by factors like temperature, aeration, and concentration and type of medium components (Tsuchiya et al. 1952; Lazic et al. 1993; Purama and Goyal 2005; Bejar et al. 2013).

**The microorganisms used for the production of dextran (*Leuconostocmesenteroides*, *Saccharomyces cerevisiae*,**

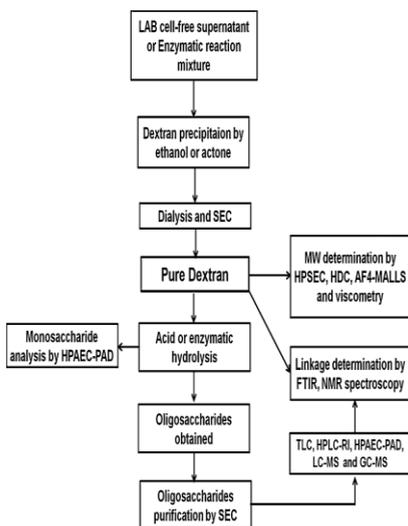
*Lactobacillus plantarum*, *Lactobacillus sanfrancisco*) are currently used in food processing without any restriction(U.S.Food and Drug Administration ,Code for Food Regulations). Dextran due to its numerous industrial applications it is being produced commercially using the strains of *Leuconostocmesenteroides* NRRLB – 512F (Shah Ali U. L. Qadar et al 2008). Dextran production is also influenced by solubility, viscosity, nitrogen, phosphorus, and ash content of the medium (Jeanes et al. 1954). The molecular weight of dextran is inversely proportional to the concentration of enzyme and directly proportional to the concentration of sucrose. Moreover, the molecular weight of dextran increases as the temperature increases from 20 C to 30 C (Falconer et al. 2011).

### **Dextran Purification**

The structural analysis of dextran starts with its isolation in pure form in such a way that the chemical and physical properties are not affected (Leemhuis et al. 2013). The recovery or purification from culture medium or enzymatic reaction mixture generally involves the following steps: (i) cell removal by centrifugation or filtration in case of culture medium, (ii) dextran precipitation from the cell-free supernatant or enzymatic reaction mixture by the addition of water -miscible organic solvents (e.g., ethanol , acetone, etc.), (iii) re-precipitation and dialysis of dextran, and (iv) size-exclusion chromatography (SEC) of dextran (Vettori et al. 2012; Shukla et al. 2014; Das et al. 2014). The high molecular weight dextran can be purified by SEC; however, low molecular weight dextran can be purified by ultrafiltration.



**Fig. 4** Structure of dextran showing  $\alpha(1 \rightarrow 6)$  glycosidic bonds in main chain and possible branches of smaller chains with  $\alpha(1 \rightarrow 2)$ ,  $\alpha(1 \rightarrow 3)$ , or  $\alpha(1 \rightarrow 4)$  linkages



**Fig. 5** A general strategy for the characterization of dextran

### Enzymatic synthesis and purification of dextran

About 10 ml reaction mixture containing 1.0 mL enzyme (0.44 mg mL<sup>-1</sup> of specific activity 20.0 U mg<sup>-1</sup>), 10% sucrose, 0.3 mM CaCl<sub>2</sub> and 15 mM sodium azide in 20 mM sodium acetate buffer, pH 5.4 was incubated at 28 C for 24 h. The dextran produced by enzymatic treatment was purified by adding three

volumes of ethanol (100%, v/v) and centrifuging the precipitated dextran at 17 200g at 25 C for 20 min. The supernatant containing fructose and the left over sucrose was discarded. The dextran pellet was washed thrice with three volumes of ethanol (100%, v/v) and suspended in deionized water and frozen at 20 C. The frozen dextran was freeze dried using a lyophilizer (Christ GmbH, model ALPHA 1-4 LD, Christ GmbH, Osterode, Germany) at 51 C at a vacuum pressure of 35 10 3 mbar for 24 h and stored at 4 C for further characterization.

### **Molecular mass analysis of purified dextran**

The average molecular mass of dextran was determined by gel filtration using Sephacryl S 500HR (Sigma Chemical Co., St. Louis, MO) on a Fast protein liquid chromatography system (FPLC, Akta Prime, GE Healthcare, Amersham, UK). Dextran 70 kDa, 200 kDa, and 2000 kDa (Sigma Chemical Co., St. Louis, MO) were used as standards. Dextran samples of 2.0 mL (2 mg mL<sup>-1</sup>) were applied through sample injection port to (40 1.6 cm) glass column packed with Sephacryl S-500 HR matrix, pre-equilibrated with degassed milli-Q water (18 M X). It was eluted with degassed milli-Q water at constant flow rate of 1 mL min<sup>-1</sup> at 30 C. The fractions (3.0 mL) were collected through fraction collector (GE healthcare, Frac-920) and analyzed for total carbohydrate using the phenol–sulphuric acid method (Fox & Robyt, 1991). Molecular mass of dextran was calculated by constructing a calibration curve in which logarithm of the molecular mass of dextran standards was plotted as a function of elution volume as described by Wang et al. (2012).

## **PROPERTIES OF DEXTRAN**

### **Physicochemical Properties**

Dextran polymers have a remarkable diversity in chain length and in physicochemical properties due to the variation in degree of branching in their glucose backbone. In general, dextran is readily soluble in water, dimethyl sulfoxide, formamide, ethylene glycol, and glycerol but insoluble in mono hydric alcohols, e.g., methanol, ethanol, and isopropanol, and also most ketones, e.g., acetone and 2-propanone. However, the water solubility of dextrans depend s upon the branched linkage pattern . Linear dextrans have high water solubility, and the aqueous solutions behave as Newtonian fluids. However, some branched dextrans showed shear rate thinning effect, exhibiting non -Newtonian pseudoplastic behavior (Das and Goyal2014).

Viscosity of dextran solution depends on its concentration, temperature, and molecular weight. As dextran is a neutral polysaccharide, the viscosity is not significantly influenced by changes in pH or salt concentration. Dextrans with >43 % branching through  $\alpha$ -(1  $\rightarrow$  3) linkages are water insoluble.

### **Structural Properties**

The specificity of the synthesized linkages in the dextran is strain dependent. The most studied dextran is produced by *Leuconostocmesenteroides*NRRL B-512 F. It contains 95 %  $\alpha$ -(1  $\rightarrow$  6) linkages and 5 %  $\alpha$ -(1  $\rightarrow$ 3)-branched linkages (Naessens et al. 2005; Vettori et al. 2012). *L. mesenteroides*NRRL B-742 produces a dextran with 87 %  $\alpha$ -(1  $\rightarrow$  6) linear linkages and 13 %  $\alpha$ -(1  $\rightarrow$ 4)-branched linkage. The strain *L. mesenteroides* NRRL B-1299 produces a rare kind of dextran with 63 %  $\alpha$ -(1  $\rightarrow$  6), 27 % of  $\alpha$ -(1  $\rightarrow$  2), and 8 % of  $\alpha$ -(1  $\rightarrow$  3) linkages (Remaud-

Simeon et al. 2000).The molecular structure of dextran is shown in **Fig. 4**.

### **Applications of Dextran**

Dextran are used in the manufacture of blood plasma extenders, heparin substitutes for anticoagulant therapy, cosmetics and other products(Leathers et al 1995; Sutherland 1996; Alsoop 1983; Kim and Day 1994).Another use of dextran is the manufacture of sephadex gel beads which are widely used for industrial and laboratory protein separations( Sutherland 1996).

### **MEDICAL USES**

#### **Antithrombotic effect:**

These agents are used to decrease vascular thrombosis. The antithrombotic effect of dextran is mediated by its binding of erythrocytes, platelets and vascular endothelium, increasing their electronegativity and thus reducing erythrocytes aggregation and platelet adhesiveness. Dextran also reduce the VIII-Ag Von Willebrand factor, thereby decreasing platelet function. Clots formed after administration of dextran are more easily lysed due to an altered thrombus structure. By inhibiting alpha – 2 antiplasmin, dextran serves as a plasminogen activator and therefore possesses thrombolytic features. Apart from these features larger dextrans, which do not pass out of the vessels are potent osmotic agents, and thus have been used to treat hypovolemia. The hemodilution caused by volume expansion with dextran use improves blood flow, thus further improving patency of microanastomoses and reducing thrombosis (Chris I. Jones et al 2008).

### **Usage in intravenous fluids:**

It is used in some eye drops as a lubricant and in certain intravenous fluids to solubilize other factors. Dextran in intravenous solution provides an osmotically neutral fluid that once in the body is digested by cells into glucose and free water. It is occasionally used to replace lost blood in emergency situations, where replacement blood is not available, but must be used with caution as it does not provide necessary electrolytes and can cause hyponatremia or other electrolyte disturbances (Fischer 1985).

### **Anticoagulant activity:**

Chemically prepared sulphuric esters of polysaccharides are known to have anticoagulant action. One of these is the dextran sulphate. The anticoagulant expressed in units/mg appears to be independent of the molecular weight but depends on a certain minimum number of sulphate groups per glucose units. Clinical grade Dextran are available as Dextran 1, Dextran 40, Dextran 60 and Dextran 70. Solutions of Dextran 40, Dextran 60 and Dextran 70 for injections are commonly used in clinical practice for replacement of blood loss, plasma substitution, thrombosis prophylaxis, volume expansion rheological improvement. Administration of Dextran 1 prior to injection of Dextran 40, Dextran 60 and Dextran 70 is known to reduce the adverse reactions significantly. Clinical grade dextran is the safest plasma substitute in clinical use. Clinical grade dextran are used for different purposes example cryopreservation and solutions for storing organs for transplantation and as carriers in vaccines (Fischer 1985).

### **Food Applications of Dextran**

Dextran has been studied as a food ingredient since the 1950s. The US Food and Drug Administration (US FDA) currently lists dextran as GRAS (generally recognized as safe) additive

for food and feed applications. In general, dextran is used as gelling, viscosifying, texturing, and emulsifying agent in various food products (Leemhuis et al. 2013).

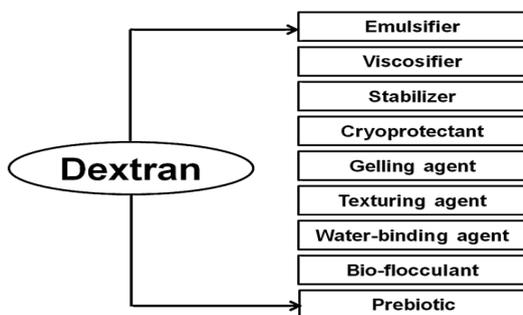
Commercial applications of dextran from LAB are generally found in food and pharmaceutical industry; however, dextran also has several potential applications in photo film manufacturing, fine chemical, cosmetic, paper, petroleum , and textile industries (Naessens et al. 2005; Leemhuis et al. 2013). Due to the heterogeneity of dextran produced by various LAB, their application may depend on well-defined chemical and physicochemical properties.

**Table 4 Food applications of dextran**

Applications	References
<b>Bakery</b> Improves freshness, mouthfeel, softness, crumb texture, loaf volume, and shelf life	Katina et al. (2009)
<b>Confectionary</b> Improves moisture retention and viscosity and inhibits sugar crystallization and as gelling agents in gum and jelly candies	Maina et al. (2011)
<b>Fermented dairy products</b> Increases viscosity and creaminess and reduces syneresis	Mende et al. (2013)
<b>Ice cream</b> Cryoprotectant	Naessens et al. (2005)
<b>Frozen and Dried foods</b> Protection from oxidation and chemical changes and preservation in texture and flavor	Bhavani and Nisha (2010)
<b>Cheese making: reduced-fat cheese</b> Improves water binding and increases moisture content in the nonfat substances	Awad et al. (2005)
<b>Prebiotics</b> Functional food	Olano-Martin et al. (2000), Sarbini et al. (2013), Rao et al. (2014), Das et al. (2014)
<b>Protein–dextran conjugates</b> Improves emulsifying, foaming, gelling, and solubility attributes of protein by Maillard reaction	Zhang et al. (2012), Chen et al. (2014), Spotti et al. (2014)

The properties of dextran that are applied in food industry are shown in **Fig. 6**. Long-chain, high molecular weight polysaccharides that dissolve or disperse in water to give

improved rheological (gelling, thickening) or physicochemical (emulsion stabilization, particle suspension, etc.) properties are important for food product formulation. A current consumer trend towards healthy and additive-free food has made the dextran an attractive food ingredient (**Table 4**). The microorganisms such as *Leuconostocmesenteroides*, *Saccharomyces cerevisiae*, *Lactobacillus plantarum*, and *Lactobacillus sanfrancisco* are used for the production of dextran for its application in food processing without any restriction.



**Fig. 6 Properties of dextran used in food industry**

### **Bakery**

The incorporation of dextran in bread for the improvement of rheological properties and quality is gaining interest (Galle et al. 2012; Wolter et al. 2014). The increasing knowledge of sourdough fermentation generates new opportunities for its use in the bakery field. In situ dextran production from *Weissella* sp. and *Leuconostocmesenteroides* improved the freshness, mouthfeel, texture, loaf volume, softness, and shelf life of sourdough wheat bread (Katina et al. 2009; Galle et al. 2012). It came forth that dextran should have a high molecular weight and few branched linkages for the application in sourdough (Lacaze et al. 2007). The European Commission has approved the use of dextran in baked goods, up to the levels of 5 %.The

addition of 2 % native dextran increases the water absorption of flour dough by about 12 %. However, in situ formation of dextran in sourdough was reported to be more effective than external addition (Brandt et al. 2003). High molecular weight dextrans of (1–2)  $10^6$  Da have been approved by the European Union as food ingredients in bakery products (Naessens et al. 2005). The required molecular mass has been reported to be from 2  $10^6$  to about 4  $10^6$  Da (Katina et al. 2009).

Incorporation of sourdough to a gluten- free formula gained interest recently in bread making. Dextran from *Weissella* and *Leuconostoc* species improves dough rheology and bread texture and can be used to replace nonbacterial hydrocolloids such as guar gum and hydroxypropyl methylcellulose for the generation of gluten-free soft bread with good texture and shelf life (Tieking and Ganzle 2005; Galle et al. 2012). Hence, dextran holds potential application in baking industry for the generation of glutenfree food products for patients suffering from celiac disease (Schwab et al. 2008; Galle et al. 2010; Rao and Goyal 2013).

### **Confectionery**

Dextran is used for maintaining flavor, viscosity, moisture, inhibition of sugar crystallization, and as gelling agent in gum and jelly candies in confectioneries (Maina et al. 2011). It is also used in soft drinks, flavor extract, milk beverages, and icing.

### **Ice Cream**

Dextran is also used as a cryoprotectant in ice cream (Naessens et al. 2005). Dextran is bland, odorless, tasteless, and nontoxic and is considered to have many advantages over other ice cream stabilizers. Ice cream mixes containing 2–4 % dextran conferred beneficial properties on viscosity (Bhavani and Nisha 2010).

### **Fermented Dairy Products**

The texture of yogurt and yogurt-like products made from milk by fermentation with LAB can be modified by in situ production of EPS (Cerning 1995). EPS produced by LAB, particularly dextran, positively affected the rheological properties of acidified milk gels with enhanced viscosity, creaminess, and reduced syneresis because of its water-binding ability (Mendeet al. 2013) and hence can replace the commercially used texturizers, viz., xanthan, carrageenan, pectin, guar gum, and  $\beta$ -glucan.

### **Frozen Foods**

The favorable properties of dextran for stabilizing vacuum, air-dried, and freeze-dried or frozen foods enable the use of dextran in fish products, meat, vegetables, and cheese. A film of dextran could protect food from oxidation and other chemical changes and also help to preserve texture and flavor. The increasing demand for fast food in frozen or dried state creates an opportunity for the use of dextran as a preservative, as well as a texture, flavor, and smell enhancer (Bhavani and Nisha 2010).

### **Reduced-Fat Cheese**

The fat reduction in cheese results in many textural and functional defects. The high casein content in reduced-fat cheese imparts a firm and rubbery body and texture. Dextran is a good candidate for making reduced-fat cheese for several reasons. Dextran has the ability to bind water and increase the moisture in the non-fat mass (Awad et al. 2005).

### **Prebiotics**

In recent years, there is a considerable interest in the use of prebiotics as functional foods in order to modulate the composition of the colonic microbiota to provide health benefits to the host (Saad et al. 2013). Foods containing prebiotic have

also been associated with the protection against risk of several diseases, viz ., bowel cancer, inflammatory bowel disease, diarrhea, coronary heart disease, obesity, osteoporosis, cholesterolemia, and type 2 diabetes. The  $\alpha$ -(1  $\rightarrow$  6) linkages are known to be resistant to hydrolysis by human intestinal enzymes, which results in the slow digestion of dextran in human. Moreover,  $\alpha$ -(1  $\rightarrow$  2) linkages are also highly resistant to the attack of digestive enzymes (Remaud-Simeon et al. 2000). Dextran and dextran-derived oligosaccharides have also been reported to increase the fraction of Bifidobacterium species in an in vitro model of the fermentation process in the human colon exhibiting prebiotic activity (Olano-Martin et al. 2000). A low molecular weight dextran containing  $\alpha$ -(1  $\rightarrow$  2)-branched linkages was also reported to act as prebiotic with selective effect on the gut microbiota (Sarbiniet al. 2013). This dextran induced the growth of beneficial bacteria such as Bifidobacterium sp. and Lactobacillus sp. Recently, dextrans from *Weissellacibaria* JAG8 (Rao et al. 2014) and Lactobacillus plantarum DM5 (Das et al. 2014) showed promising prebiotic potential with very low gut digestibility and selective stimulation of probiotics.

### **Protein: Dextran Conjugates**

Proteins are widely used in the food products such as beverages, yogurt, mayonnaise, and ice creams due to their functional properties, viz., emulsifying, foaming, gelling, and solubility (Oliver et al. 2006; Zhang et al. 2012).

The functional properties of proteins can be improved by the conjugation of proteins and polysaccharides through Maillard reaction (Spotti et al. 2014). The Maillard reaction or nonenzymatic browning refers to any chemical reaction involving the interaction between amines and carbonyl compounds. Maillard reaction adds to the aroma, taste, and

color of coffee and cocoa beans, bread, cakes, cereals, and meat (Martins et al. 2001).

Dextran-conjugated proteins have displayed significant improvement in physical and chemical properties of proteins, such as thermal stability, emulsification, and antioxidant properties (Zhu et al. 2010).

## **CONCLUSION**

From the facts outlined above it appears that Dextran the branched polysaccharide supposedly has many health benefits. Apart from which it contributes to many more applications in technical and pharmaceutical industries too. It has been recognized the necessity to encourage the industrial production of dextran using cheaper substrates considering the economic strategies.

The sources, preparation, characterization, and food applications of dextran have been described. The biocompatibility, high water solubility, and water-holding capacity make dextran an important food ingredient. Therefore, the hunt for new, novel sources of dextran seems to be an interesting quest for food applications. Moreover, the production of dextran using cheaper substrates such as food wastes and agricultural by-products is prerequisite for its economic recovery at industrial level. Dextran conjugation has aided the design of new tailor-made polymers with different molecular weights, shapes, structures, and functional activities. It will be useful from an application viewpoint, if the functional properties of dextran, viz., rheology, molecular weight distribution, degree, and length of branching, and the fine structure of the dextran-conjugated products would be explored in greater details. The identification and characterization of novel dextransucrases with random mutagenesis followed by

high throughput screening will provide the best methods to obtain novel types of dextrans.

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