Prebiotics from lignocellulosic material



Lignocellulosic Biomass



Prebiotic precursor
(Xylan)



Prebiotic (XOS)

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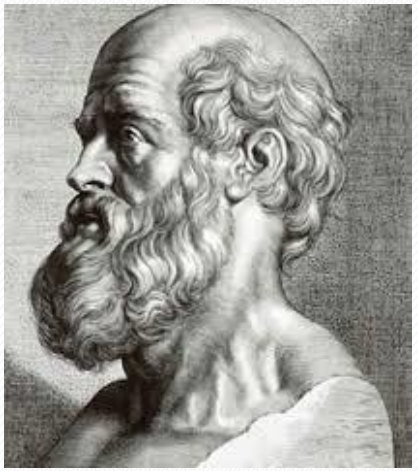
- Lives with nature
- Depends on natural foods
- Successful in charging the body with naturally occurring bioactive molecules

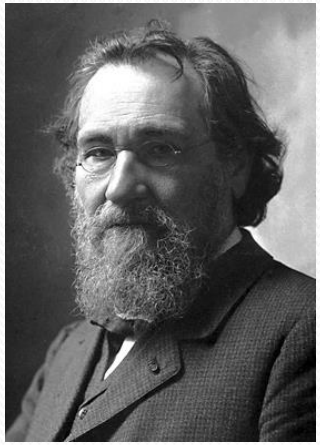
- Increased healthcare expenditure
- Phobia against modern therapeutic agents
- Prefers plant sourced bioactives



Historical background

About 460 to 370 BC, Hippocrates, the great ancient Greece physician told: "Let food be thy medicine and medicine be thy food". Evidently, he emphasized on prevention rather than cure of diseases.





In 1907, E. Metchnikoff proposed the concept of longevity that is taking care by beneficial gut microflora from the observation at Village in Bulgaria. Concept of probiotic emerges.

Present Concerns

Human health
Food safety
Animal welfare
Consumer awareness
Restriction on application of antibiotics
Environmental issues

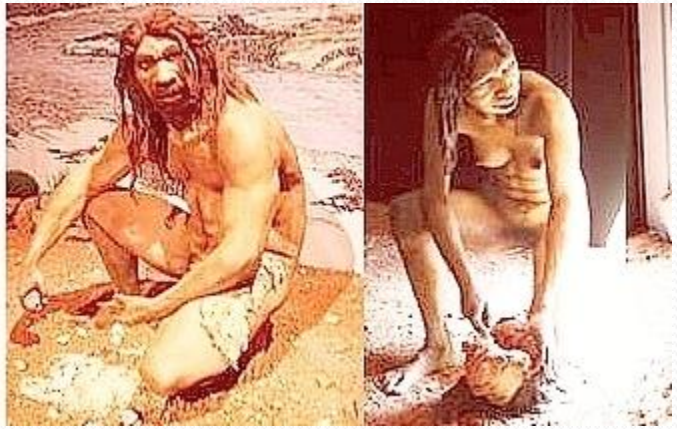
Evolution of Prebiotic Concept



What is prebiotic?

A non-digestible dietary ingredient that beneficially affect the host by selectively stimulating the growth and or activity of a limited number of bacteria in the colon, thus improving host health (Gibson and Roberfroid, 1995).





However, ancient Indian knew about prebiotic since Sindhu civilization and selectively choosing the crops rich in prebiotic (Samanta et al., 2010)

With the growing interests and intense research and development activities on prebiotic, it has been proposed to revisit its definition and suggested to exclude the word 'non-digestible'.

The updated definition of prebiotic encompasses as "a selectively fermented ingredient that allows specific change, both in the composition and or activity in the GI microflora that confers benefits upon host well being and health" (Gibson et al., 2004)

Prebiotics are: non-viable food components, ingredients or supplements that selectively modulate the microbiota of the digestive ecosystem, thus conferring benefits upon host well being and health" (Roberfroid, 2007)

According to FAO (2007), "a prebiotic is a non-viable food component that confers a health benefit on the host associated with modulation of microbiota".

Further, attempt has been made to broaden the site of action of prebiotics such as skin, oral cavity and female genital tract in addition to its fundamental action at the GI tract (Pineiro et al., 2008).

Recently, the proposers of prebiotic concept have opposed the philosophy of broadening the its application sites such as vagina and skin and wanted to restrict once again to the gastrointestinal microflora.

Therefore, the accepted definition remains closer to the 1995 concept: "a prebiotic is a selectively fermented ingredient that results in specific changes in the composition and /or activity of the gastrointestinal microbiota thus conferring benefit(s) upon host health" (Gibson et al., 2010).

It seems emphasis was given on prebiotics keeping in view its application in human beings only.

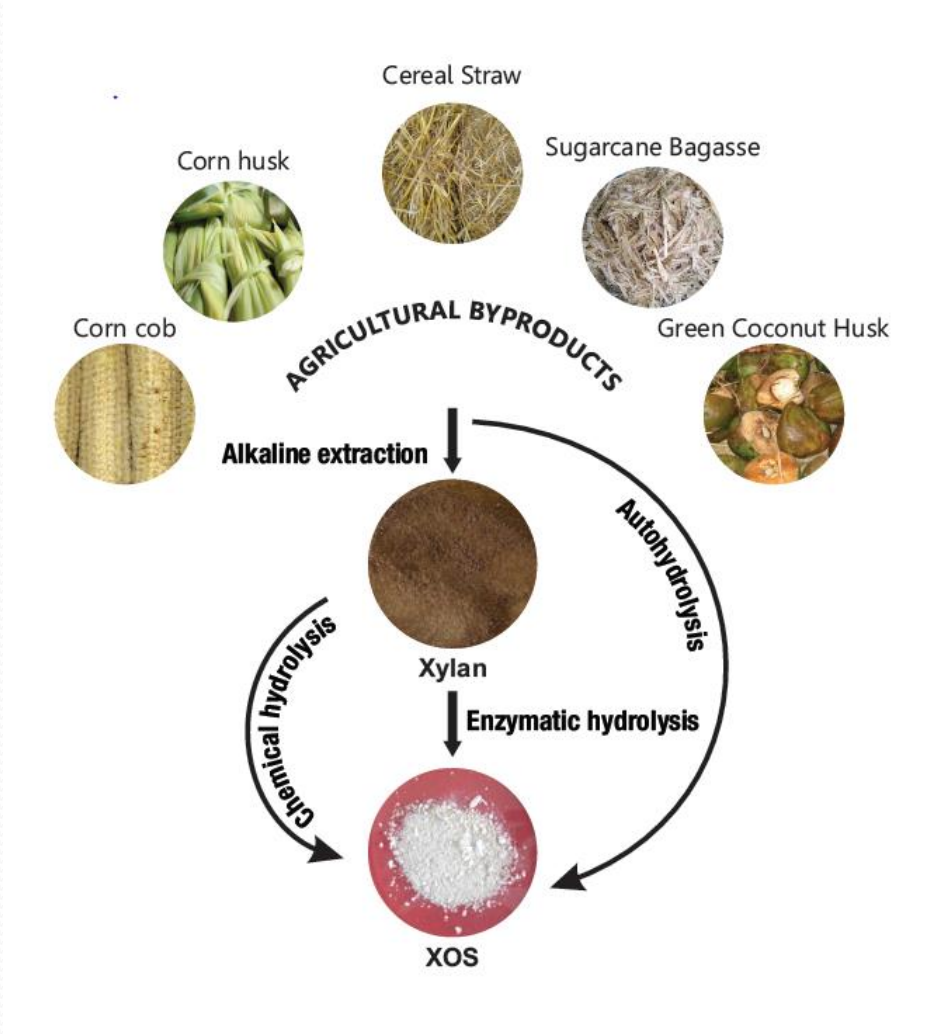
Thus, Samanta et al. (2007, 2013, 2015) suggested following criteria for prebiotics keeping in view the digestive system of both human and animals

- Selective fermentability
- Desirable changes in gut microflora composition
- Ensures host health and well being
- Originated from plant or synthesized by microbial enzymes
- Remains intact while passing through digestive tract
- No residue problems
- Compatibility with other food/ feed / products
- No adverse affects on productivity or product quality
- Should increase nutrient digestibility or reduce enteric methane emission in ruminants

Common prebiotic

- Inulin
- Fructo-oligosaccharides (FOS)
- Glacto-oligosaccharides (GOS)
- Pectic oligosaccharides (POS)
- Soya oligosaccharides
- Mannan-oligosaccharides (MOS)
- Tagatose
- Xylooliogosaccharides (XOS)

Prebiotic from Lignocellulosic Biomass



(Samanta et al., 2015)

Lignocellulosic Materials















Disposal problems
Invites insects
Burn at field



Steps in prebiotic production from Lignocellulosic materials

Identification raw material/ wastes

Compositional analysis

Xylan extraction

Room temperature | Steam application



Prebiotic production

Chemical process | Enzymatic process



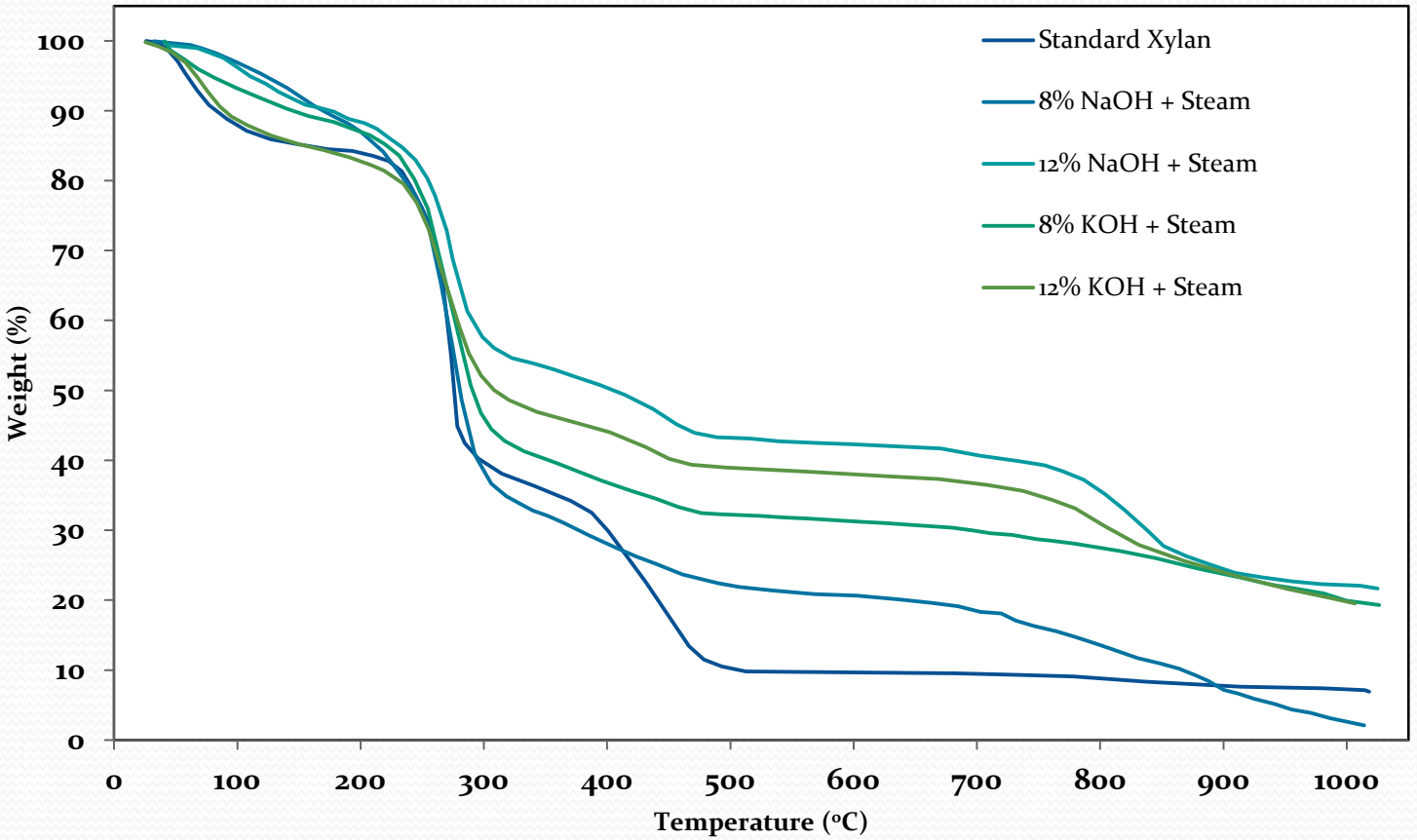
Identification of raw materials for XOS production

Agricultural biomass	Organic matter	Total ash	NDF	ADF	Hemicellulose	Cellulose	ADL	CP
Corn cob	97.71	2.29	75.89	37.11	38.78	27.16	9.40	5.2
Corn husk	97.11	2.89	68.87	31.48	37.39	29.07	2.41	2.68
Wheat bran	92.14	7.86	37.73	16.22	21.51	12.84	3.48	15.05
Rice bran	88.87	11.13	62.90	45.93	16.97	35.84	10.09	8.00
Cotton seed cake	95.17	4.83	55.26	34.97	20.29	24.89	10.08	28.49
Sugarcane bagasse	99.09	0.91	64.71	41.49	23.22	32.61	8.88	2.31
Paddy straw	82.71	17.29	73.28	48.93	24.35	44.75	4.18	3.15
Gram straw	90.30	9.70	54.32	39.66	14.66	30.47	9.19	6.4
Soyabean hulls	95.25	4.75	70.14	51.91	18.23	33.80	18.11	4.65
Ragi straw	90.31	9.69	72.63	42.93	29.70	36.96	5.97	3.38
Pigeon pea stalk	94.63	5.37	61.30	42.99	18.33	42.71	10.41	4.80
Green coconut husk	96.27	3.73	76.20	60.96	15.24	57.46	3.50	3.60
Palm press fiber	93.36	6.64	77.19	53.61	23.58	48.98	2.49	--

Methods of xylan extraction and its yield

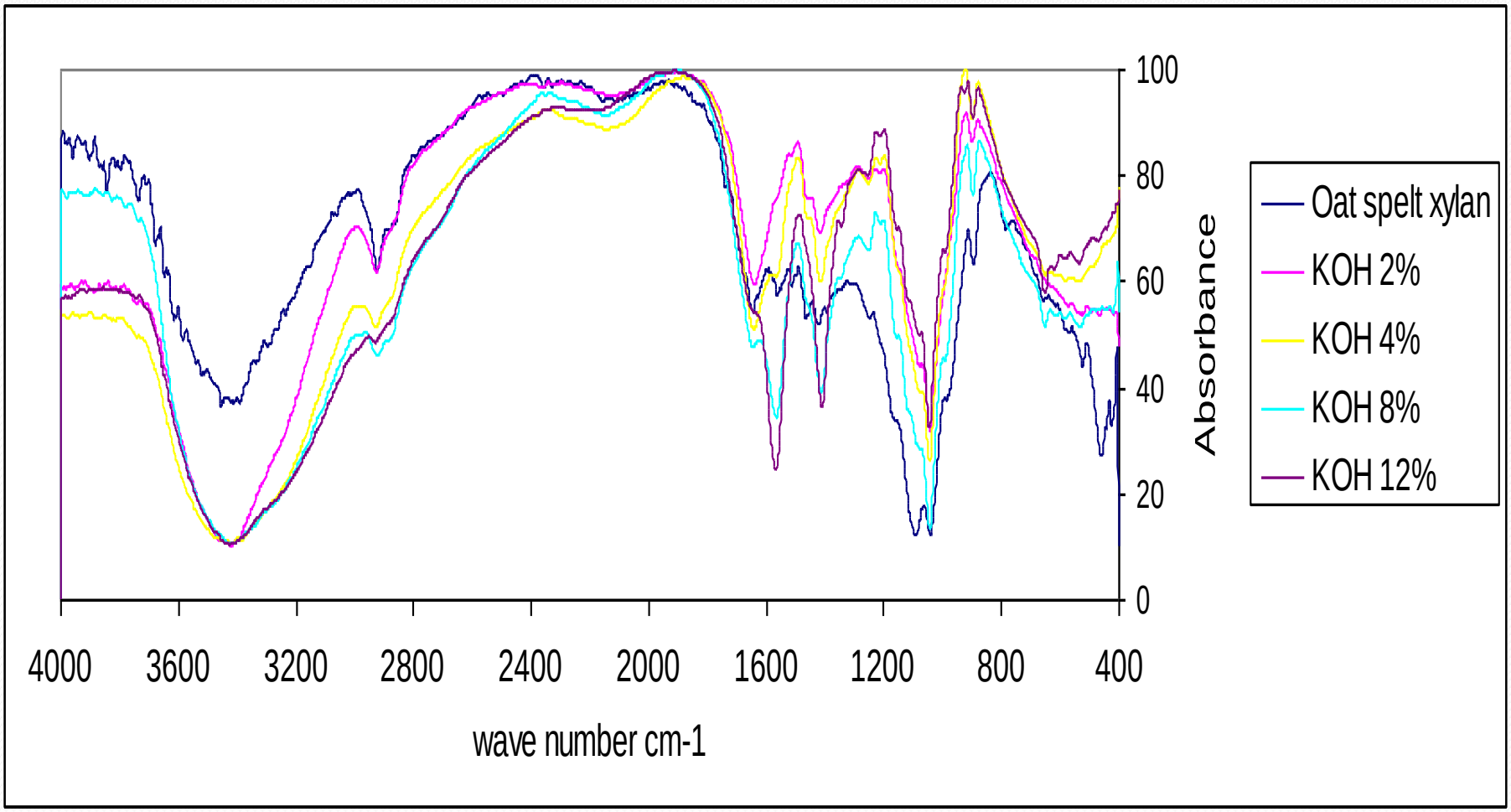
Name of raw materials	Extraction with	Yield	Reference
Cotton stalks	24% KOH+1% $NaHBH_4$	0.4 g/2 g of cotton stalks	Akpinar, Ozlem, Kavas, Bakir, and Yilmaz (2007)
Corn cobs	12% NaOH with steam	83% of original xylan	Samanta et al. (2012a)
Corn stalks	10% NaOH 20 °C	54% of original sugars	Ergues, Sanchez, Mondragon, and Labidi (2012)
Wheat straw	0.5 M NaOH at 55 °C	49.3% of original xylan	Ruzene, Silva, Vicente, Goncalves, and Teixeira (2008)
Poplar wood	NaOH coupled with sonication	75.5% of original xylan	Yuan, Xu, He, and Sun (2010)
Sugarcane bagasse	3% NaOH at 50 °C	74.9% of original xylan	Peng et al. (2009)
	12% NaOH coupled with steam	85% of original xylan	Jayapal et al. (2013)
	Two stage extraction with water and 1% NaOH	49.5% of original xylan	Peng et al. (2010)
Tobacco stalks	24% KOH+1% $NaHBH_4$	21.8% of total dried raw materials	Akpinar et al. (2009)
Sunflower stalks	24% KOH+1% $NaHBH_4$	18.9% of total dried raw materials	Akpinar et al. (2009)
Wheat straw	24% KOH+1% $NaHBH_4$	20.6% of total dried raw materials	Akpinar et al. (2009)
Natural grass	12% NaOH coupled with steam	98% of original xylan	Samanta et al. (2012)
Pigeon pea stalks	12% NaOH coupled with steam	96% of original xylan	Samanta et al. (2013)
Green coconut husks	4% KOH coupled with steam	84% of original xylan	Jayapal et al. (2014)

Quality analysis of xylan



Thermogravimetric analysis

Samanta et al., 2012



FT-IR analysis of xylan

Samanta et al., 2012

Factors influencing the XOS production

- **Source of xylan**
- **Enzyme activity**
- **pH**
- **Hydrolysis time**
- **Temperature**

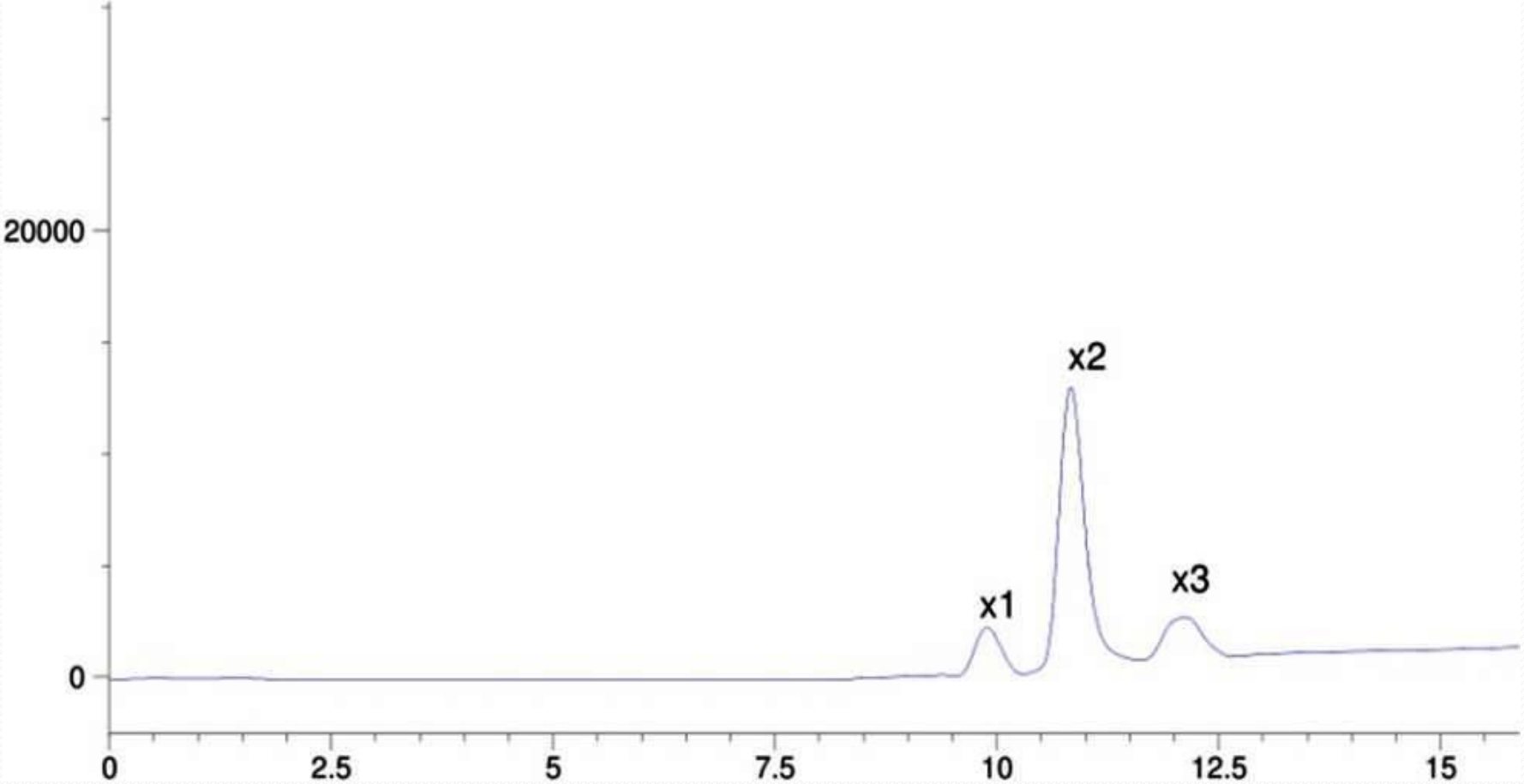
XOS yield from xylan of different lignocellulosic materials

XOS yield from corn cob, wheat bran, peanut,shell, oat spelt: Xylobiose: 3.42 to 4.7 mg/ml, Xylotriose: 0.34 to 3.66 mg/ml, Xylotetrose: nil to 1.99 mg/ml (Yang et al., 2007)

XOS yield from Sugarcane Bagasse reached up to 11 g/100g of xylan with pH 5.0, Temperature 45°C, Enzyme dose: 17.4 U/ml, Hydrolysis Time: 10 h (Jayapal et al., 2013)

XOS yield from natural grass reached Up to 7g/100g of xylan with pH: 5.0, Temperature: 40 °C, Enzyme dose: 13.2 U/ml, Hydrolysis Time: 16 h (Samanta et al., 2012)

HPLC chromatogram of enzymatic hydrolyzate of sugarcane bagasse xylan following application RSM generated variables



Jayapal et al., 2013

Chemical and biological properties of XOS

Property	Value/Nature
Molecular formula	$C_{5n}H_{8n+2}O_{4n+1}$; n=2-6
DP range	2-6
Molecular Weight (g)	282 - 810
Physical form	Crystalline solid, color depends on source of xylan/purification/process of drying
pH Stability	2-7
Sweetness	92% of sucrose
Energy Value	1.5 Kcal/gm
Absorbability at GI tract	Nil
Recommended dose	8-12g/day
Regulatory Status	GRAS

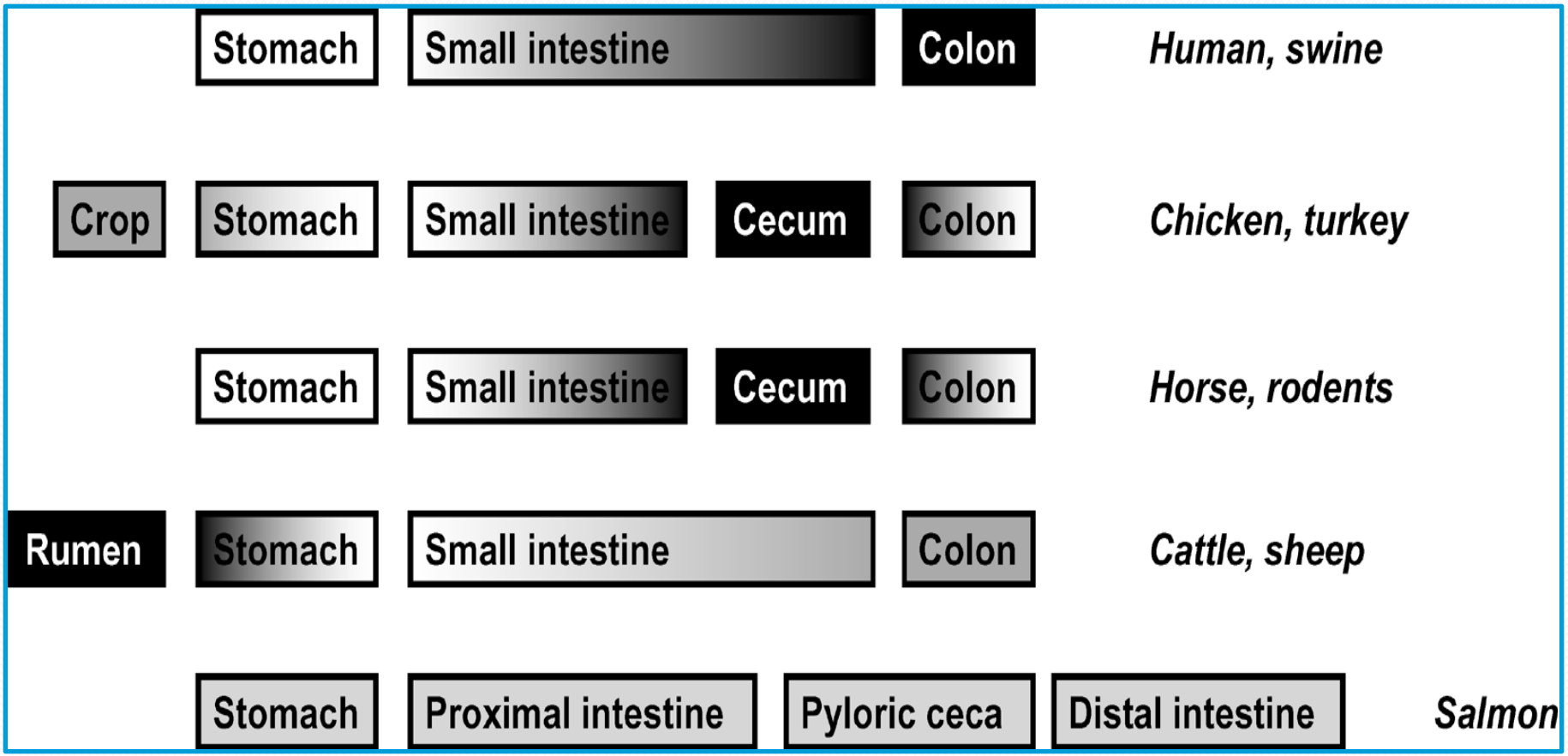
Prebiotic Action

It acts through selective stimulation of growth and multiplication of beneficial gastrointestinal microflora



Imaginary microflora composition of gastrointestinal tract

Microbial density at different segments of GI tract



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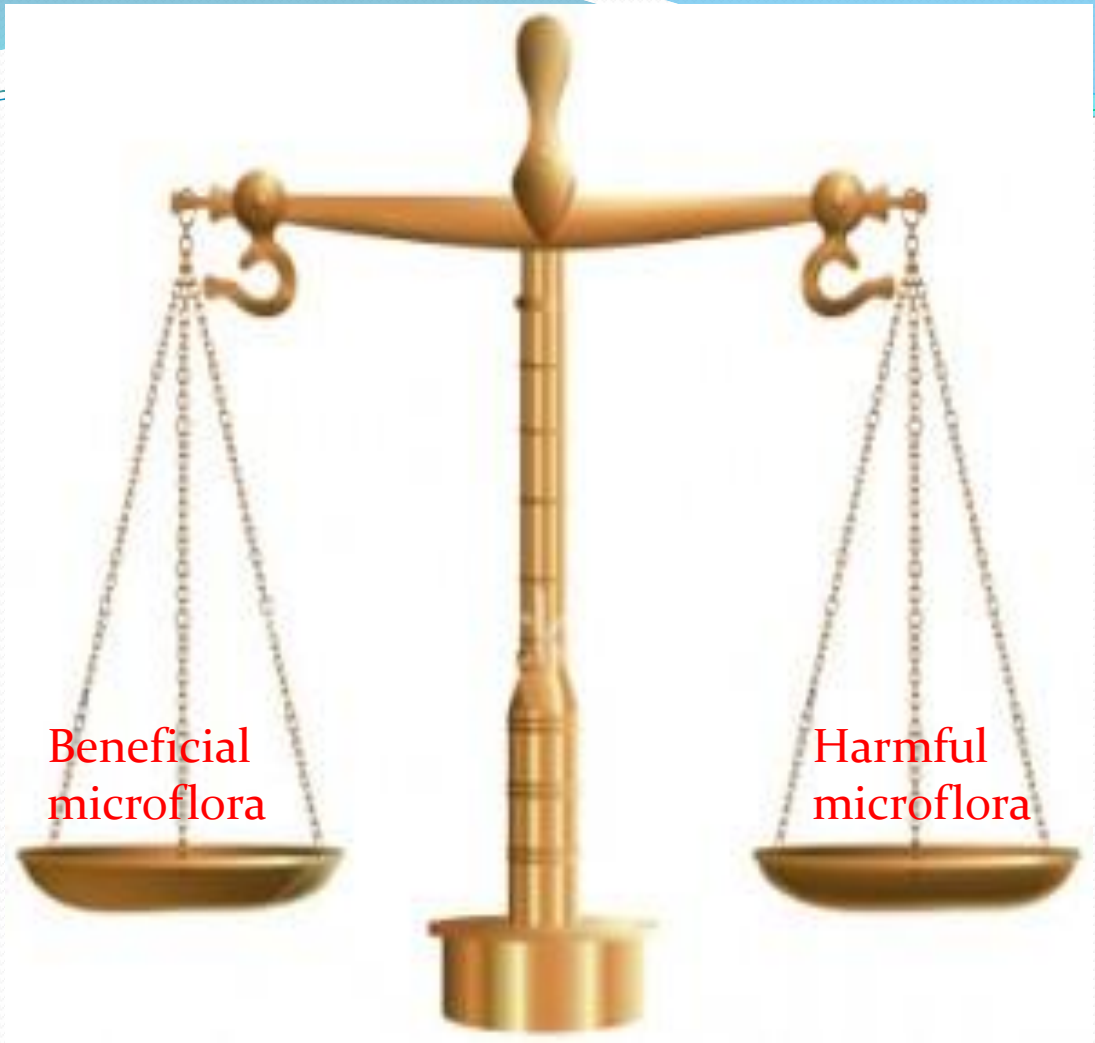
- The rich GI tract houses approximately 10^{14} bacterial cells , representing 30 known genera and 500 known species and many un-described species (Nesih, 2002, Samanta et al., 2015)

2

- 1-2 kg of bacteria in adult gut, metabolic activity is comparable to liver & tantamount to a virtual organ (Shanahan, 2002)

3

- Combined no. of genes of gut microbiome can reach 100 fold the size of human genome (Shanahan, 2002)



Prebiotic works in the principal of selective stimulation of beneficial microflora

Effect on human

- Increased Lactobacillus and Bifidobacteria
- Makes thinner gut epithelium
- Increased mineral absorption
- Reduced gut pathogens
- Makes acidic pH
- Stimulates immunity
- Reduces cholesterol, triglycerides and glucose in blood
- Posses anti-carcinogenic property
- Posses anti-inflammatory and anti-oxidant activity



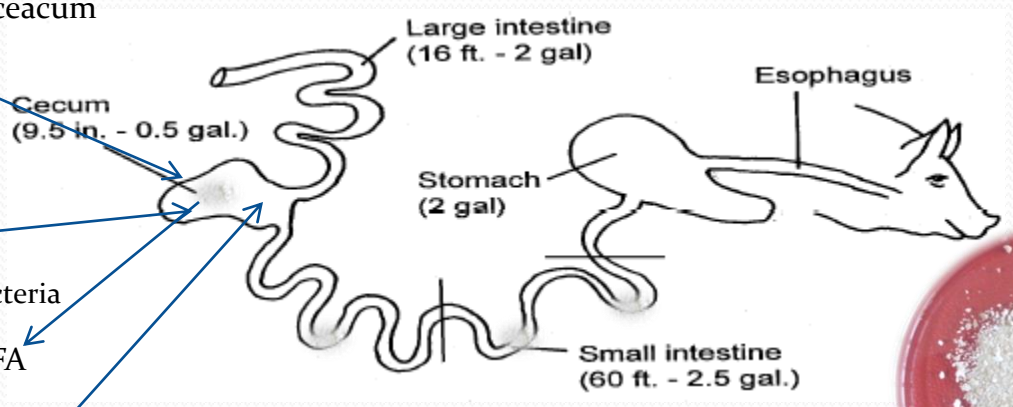
Effect of XOS in birds

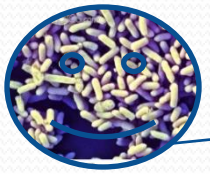


- Increased Lactobacillus and Bifidobacteria
- Makes thinner gut epithelium
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Mechanism of action of prebiotic

Reached intact at ceacum

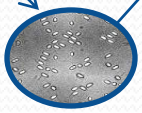




Growth of Beneficial Bacteria

Production of SCFA

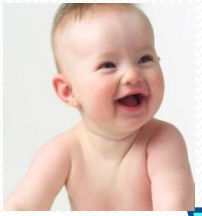
Pathogens



Ups.. Prebiotic!!!
Lets go out from
here (GUT)



Prebiotic







Prebiotic beneficial













Global prebiotic market

❖Global prebiotics market is expected to reach USD 5.75 billion by 2020, according to a new study by Grand View Research Inc.

❖Global prebiotics market was 581.0 kilo tons in 2013 and is expected to reach 1,084.7 kilo tons by 2020, growing at a CAGR of 9.3% from 2014 to 2020.

❖Asia Pacific is expected to be the fastest growing market in terms of volume, growing at a CAGR of 9.6% from 2014 to 2020 on account of surging demand.

❖Key companies include Friesl and Campina Domo, Cargill inc., Beghin Meiji, Beneo-Orafti SA, Roquette America, Inc., Cosucra Groupe Warcoing SA and Weetabix Ltd.





Sharing My Secrets of Health

Everyday I dose with prebiotic.
Do you?



Healthy society



Future of us will be better and healthy; if we believe & rely on plant sourced bioactive molecules such as prebiotics

Thank you