THE WORLD OF EDIBLE ALLIACEE

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Contents

Summary

During the 2000s, there has been vast expansion in the research of fructooligosaccharides (FOS), including their chemistry, biochemistry, and enzymology in living organisms, as well as nutritional and health benefits. However, in spite of these considerable advances in FOS science, many other aspects of the mechanisms of FOS behind their involvement in well being have not been fully understood. FOS constitute a major part of the dry matter of edible *Allium* species, and the knowledge of the mechanisms of their mode of action in human metabolism are of great interest. Significant progress has been made in the chemical, nutritional and clinical research areas of *Allium* FOS, as well as on other FOS, and in addition to their role as quality attribute, FOS participate in other processes. This paper aims to review the occurrence, chemistry and health benefits of *Allium* species' FOS including nutritional contribution of FOS in health and well being.

1. Introduction

1.1. History of Edible *Allium* Species

Allium species (or *Allii*) are supposed to be ones of the world's oldest cultivated vegetables and large was reported on them. It is presumed that our predecessors discovered and consumed wild *Allium* species long before farming or writing was invented. Because *Allium* species are small and leave no archaeological evidence, the exact origin remains still mysterious. Onion and garlic could probably be the first cultivated *Allium* crops due to their growing versatility, long storage time, and portability. They could be dried and preserved for times when food was scarce. The Chinese have cultivated *Allium* species in gardens for 5000 years, and have been referenced in the ancient Vedic writings of India. *Allium* species can be traced back as far as 3500 B.C. in Egypt, where they served as an object of worship. The onion symbolized eternity to the Egyptians who buried the root vegetable alongside Pharaohs.

1.2. Taxonomic History

The genus *Allium* contains more than five hundred species, including many ornamental and edible plants. The genus has been assigned to the family Alliaceae, although for many years it was classified with both the Amarylidaceae and the Liliaceae. Edible *Allium* species are important staples in the diets of many of the world's cultures (Table 1).

Common name	Botanical name	Country
Common chives	*A. schoenoprasum*	Germany, The Netherlands, Denmark, New Zealand, Peru,
Chinese chives	*A. tuberosum*	China, Korea, India Japan, Thailand, Indonesia, The Netherlands
Rakkyo (Japan)	*A. chinense* syn. *A. baken*	China, Japan" Korea, Bawang ganda (Indonesia) Indonesia, California
Ever-ready onion	*A. cepa* aggregatum group syn. *A. cepa* V8f. *perutile*	UK
Grise de la Drôme	*A. ascalonicum?*	southern France
Ciboule Vivace Johanniszwiebel Johannis1auch Utrechtse Sint Jansui	*A. lusitanicum?*	France Germany Germany The Netherlands
Tree onion	A. × *prolijerwn* and many synonyms	Germany, Siberia Japan. Iran (Kashmir)
Wakegi onion	*A. × proliferum* syn. *A. wakegi*	Japan, China
Poireau perpetuel Petit poireau Antillais Perlswiebel Pereluien Perai anak	A. *ampeloprasum* pearl onion group?	France Carribbean area Germany The Netherlands Indonesia
Kurrat	*A. ampeloprasum*, kurrat group	Egypt, Near and Middle East
Tarée irani	*A. ampeloprasum* Tarée group	Iran

Poireaux bulbeux	*A. ampelaprasum* bulbous leek group	France
Great headed garlic	*A. ampeloprasum*	southern California
Elephant garlic Pferdeknoblauch Sommerknoblauch	great headed garlic group	Russia, Egypt, Chile Greece, India
Chinese garlic Nobiru (Japan)	*A. grayi*? syn. *A. macrostemon*?	China, Japan Taiwan, Korea
?	*A. mutans*	Siberia
Green Spring sweet onion?	*A. triquetrum*	Algeria

Table 1. An exhaustive list enumerating the main *Allium* crop species cultivated throughout the world (van der Meer 1997)

Most of the edible *Allium* species are native to the mountains of central Asia, and a number of alliums are still collected from the wild in this region. Distribution of *Allium* crops ranges widely throughout the Northern Hemisphere and in mountainous regions of the tropics. The area of greatest diversity is the mountains of central Asia, including Afghanistan, Tajikistan, Pakistan, and parts of Siberia and China.

Many edible *Allium* species are classified into two subgenera, *Rhizirideum* and *Allium*. The subgenus *Rhizirideum* consists of three sections *Cepa*, *Schoenoprasum*, and *Rhizirideum* and these sections comprised the species *cepa*, *fistulosum*, *schoenoprasum*, and *tuberosum*.

On the other hand, the subgenus *Allium* consists of one section *Allium* and this section is comprised of the species *ampeloprasum*, *sativum*, and *chinense* (Hanelt, 1990; Brewster, 1994). These seven species constitute the primary and main edible *Allium* species consumed throughout the world (Fenwick and Hanley 1985) (Table 2). These authors also describe many of other *Allium* species consumed as vegetables or herbs, including the topset onion, the tree onion, the Wakegi onion, and others, although all these are minor in comparison with the seven main species. These minor *Allium* species are primarily from the *Allium* cepa group and were described in detail by Jones and Mann (1963).

At the present time, the *Allium* family has over 600 members, each differing in taste, form and color, but close in biochemical, phytochemical and neutraceutical content. Besides their remarkable medicinal powers, *Allium* species are generally consumed for their flavors, while their nutritive values have been appreciated only recently (Fenwick Hanley 1990).

Carbohydrates in *Allium* species account for a major portion of their dry matter, contributing as much as 65 to 80% of the dry weight. The principle components of the non-structural carbohydrates are glucose, fructose, sucrose and a series of fructooligosaccharides (fructosyl polymers) with degrees of polymerization (DP) up to c.a. 12 (Benkeblia et al. 2002, Brewster 1990, Darbyshire 1978, Suzuki and Cutcliffe 1989).

Species complex	Crop	Variety	Storage organs
cepa	Onion shallot	*cepa* *ascolonicum*	foliage leaf bases and bladeless leaf sheaths
fistulosum	bunching onion	NA	foliage leaf bases, bulbs absent
schoenoprasum	chive	NA	foliage leaf bases, bulbs absent
tuberosum	Chinese chive	NA	rhizomes, bulbs absent
ampeloprasum	leek kurrat great-headed garlic pearl onion	*porrum kurrat holmense sectivum*	bulbs generally absent, cloves like garlic in great-headed garlic and pearl onion; pseudostem in leek and kurrat
sativum	garlic	*sativum*	swollen, bladeless sheaths (cloves)
chinense	rakkyo	NA	swollen, foliage leaf bases, bulbs prominent

Table 2. The seven primary edible *Allium* crop specie complexes (Brewster 1994)

However, it is considered that the most outstanding features in the chemical composition of *Allium* species is the large amount of the organic bound-sulfur compounds and other polyphenolic compounds. The sulfur compounds in onion and garlic, as well as shallot, leek, chive and other *Allium* species although at low level, have received a lot of attention because of their potential biological and flavor properties (Benkeblia 2007, Benkeblia and Lanzotti 2007).

1.3. Edible *Allium* Species

Interests in the potential health benefits of edible *Allium* species, mainly onion and garlic, have origins in antiquity, and are ones of the earliest documented examples of plants used for health maintenance and treatments of diseases (Block 1985, Griffiths et al. 2002, Khan 1996, Rivlin 2001). Edible *Allium* species formed an important part of the daily diet of ancient Egypt, and Pharaohs fed working class involved in heavy labor, as in building pyramids (Moyers 1996). The Jewish slaves in Egypt were fed *Allium* crops, apparently to keep them strength and increase their productivity. In ancient Greece, edible *Allium* crops were associated with strength and work capacity, and garlic formed an important part of the military diet (Moyers 1996).

By the Romans, *Allium* crops were considered as an aid to strength and endurance, and, were fed to both soldiers and sailors and were part of a ship's manifest when it set out to sea (Green and Polydoris 1993). In ancient Chinese civilization, *Allium* plants were evidently and frequently used in combination therapy as medicinal agent (Woodward 1996), and also formed a part of the daily diet particularly when consumed together with raw meat (Khan 1996).

During the middle age, knowledge of the therapeutic use of plants was gained, and *Allium* crops were thought to have medicinal and many other biological properties and thus, were grown in monasteries (Khan 1996). With onset of the renaissance, increasing attention was paid in Europe and America to the medical uses of *Allium* plants, such as other aromatic plants. Thus, onion and garlic were one of the major plants and ruling class began to adopt garlic and not to restrict its consumption to the working class.

Moreover, contemporary researches are tending, from one part to validate many of the earlier views concerning the efficacy of *Allium* plants, and from the other part seek to elucidate the mechanisms behind the actions of the major components of onion and garlic. So far, garlic (*Allium sativum* L.), onion (*Allium cepa* L.), bunching onion (*Allium fistulosum* L.), Chive (*Allium schoenoprasum*), shallot (*Allium cepa* L. var. *aggregatum*) and leek (*Alium ampeloprasum* L.) are the most important cultivated Alliacee of the *Allium* genus (Kik 2002), however, over 20 *Allium* species are locally cultivated and have been and are consumed by humans (van der Meer 1997)

2. The Chemistry of *Allium* Species

2.1. Carbohydrates and Fructooligosaccharides (FOS)

Because *Allium*'s FOS, as well as fructans, nomenclature are not simple since their structures are variables, the nomenclatures for FOS proposed by Lewis (1993), and, Waterhouse and Chatterton (1993) are first used in literature. However from the purely chemical point of view, some controversies were raised in the scientific literature concerning this nomenclature. Thus, in a recent paper, Yun (1996) has suggested that FOS are a common name for only fructose oligomers that are mainly composed of 1-kestose [GF_2 = 1 kestotriose , 1^F-β-D-fructofuranosylsucrose], nystose [GF_3 = 1,1 kestotetraose, 1^F (1-β-D-fructofuranosyl)$_2$ sucrose], and 1^F-fructofuranosyl nystose [GF_4 = 1,1,1-kestopentaose 1^F (1-β-D-fructofuranosyl)$_3$ sucrose] (Figure 1).

Thus, the simple FOS are "inulin-type' which consist of β(1-2)-linked fructose residues and found in almost all fructan-containing plant. In Liliaceae e.g. onion and garlic, a different type of FOS are present and named the inulin neo-series. These type of FOS have two β(1-2)-linked fructose chains attached to the sucrose starter unit. One chain is linked to the C1 of the fructose residue (as is also the case of inulin-type), and the other to the C6 of the glucose residue (Figure 1).

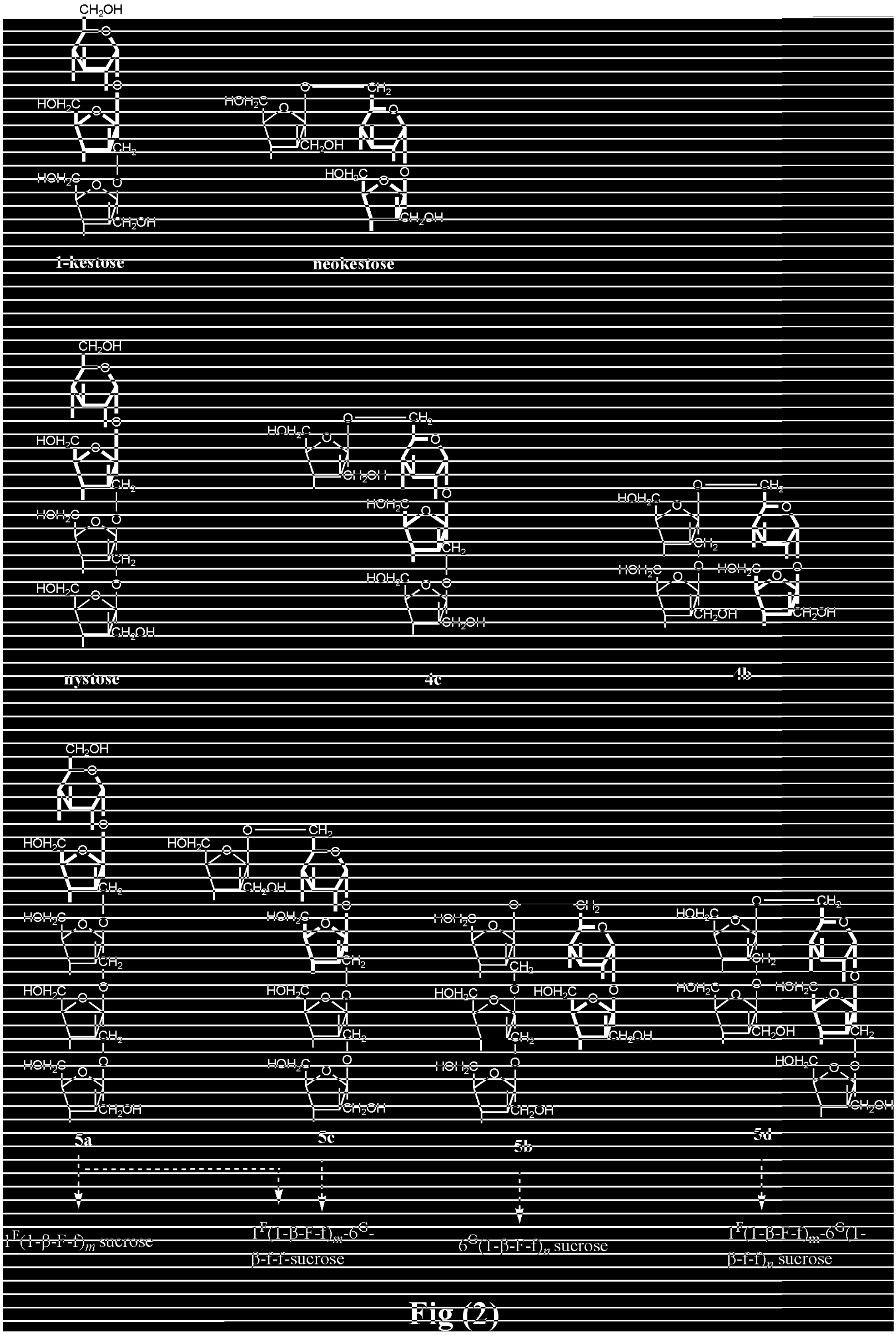

Figure 1. Molecular structures of the different fructooligosaccharides found in onion and other edible *Allium* species.

Furthermore, the analytical studies carried out on their structures were characterized by a relative lack of data because chemical and/or enzymatic methods were used to assess and to deduce high polymerized FOS on one hand, and techniques used for analyses did not allow the separation or identification of higher polymerized FOS on the other hand. Recently, new techniques for separating and determining the structural composition of the different FOS in onions have been developed. Shiomi (1993), Shiomi et al. (1991 and 1997) separated the FOS of onion bulbs using the HPAEC–PAD technique, while Stahl et al. (1997) used simultaneous MALDI-MS and HPAEC methods and obtained similar results (Table 3).

	Structure
1- Kestose (3a)	1^F–*β*–D–fructofuranosylsucrose
Neokestose (3b)	6^G–*β*–D–fructofuranosylsucrose
Nystose (4a)	1^F (1–*β*–D–fructofuranosyl)$_2$ sucrose
4b	6^G (1–*β*–D–fructofuranosyl)$_2$ sucrose
4c	1^F, 6^G–di–*β*–D–fructofuranosyl sucrose
5a	1^F (1–*β*–D–fructofuranosyl)$_3$ sucrose
5b	6^G (1–*β*–D–fructofuranosyl)$_3$ sucrose
5c	1^F (1–*β*–D–fructofuranosyl)$_2$ – 6^G–*β*–D–fructofuranosyl sucrose
5d	1^F–*β*–D–fructofuranosyl– 6^G (1–*β*–D–fructofuranosyl)$_2$ sucrose
6a	1^F (1–*β*–D–fructofuranosyl)$_4$ sucrose
6b	6^G (1–*β*–D–fructofuranosyl)$_4$ sucrose
6c	1^F (1–*β*–D–fructofuranosyl)$_3$ – 6^G–*β*–D–fructofuranosyl sucrose
$6d_1$	1^F-*β*-D-fructofuranosyl– 6^G (1–*β*–D–fructofuranosyl)$_3$ sucrose
$6d_2$	1^F (1–*β*–D–fructofuranosyl)$_2$ – 6^G (1–β–D–fructofuranosyl)$_2$ sucrose
7a	1^F (1–*β*–D–fructofuranosyl)$_5$ sucrose
7	1^F (1–*β*–D–fructofuranosyl)$_m$– 6^G (1–*β*–D-fructofuranosyl)$_n$ sucrose (m + n = 5)
8	1^F (1–*β*–D–fructofuranosyl)$_m$ – 6^G (1–*β*–D–fructofuranosyl)$_n$ sucrose (m + n = 6)
9x	1^F (1–*β*–D–fructofuranosyl)$_m$ – 6^G (1–*β*–D–fructofuranosyl)$_n$ sucrose (m + n ≥ 7)

Table 3. The structural composition of the different fructooligosaccharides of onion bulb separated by HPAEC.

The occurrence of FOS in some *Allium* species has been known since 1894 as reported by Archbold (1940), and later almost all the investigation carried out focused on onion bulbs, two on garlic while none on leek, shallot, chives or other edible *Alliums*. Their content, distribution and structure were first investigated during the 1970s by Bacon (1959) and Darbyshire and Henry (1978 and 1981). Later, FOS content and distribution were subjects of vast investigation (Benkeblia et al. 2004, Benkeblia et al. 2005, Campbell et al. 1997, Jaime et al. 2001, O'Donoghue et al. 2004). Thus, the advanced analytical techniques led to an ideal separation and identification of the different FOS found in onion bulbs [23].

However, this composition varies, although slightly, according the type of *Allium*, cultivar, dry matter content and stage of maturity (Brewster 1994), and also the content of the FOS increases from the outer (old) to the inner (young) scales (Darbyshire B, Henry 1978). It has been noted that content of low-DP FOS is correlated to that of dry matter (DM < 10%) (Darbyshire and Steer 1990), while in high dry matter onion bulbs, the maximum degree of polymerization is between 10 and 15 (Ernst et al. 1998, Suzuki and Cutcliffe 1989).

In garlic, few studies investigated the presence of FOS. Das and Das (1978) studied the structure of the fructans in garlic bulb and suggested that FOS are linear and have inulin-type structure. Recent results showed that fructans of garlic belongs to the inulin neo-series type, and later Baumgartner et al. (2000) isolated a high molecular weigh fructans, and studied their structure by enzymatic, chemical and NMR spectroscopy and confirmed the inulin neo-series structure. Leek, shallot and other edible *Allium* species, no data are available regarding the structure of their nonstructural carbohydrates, and the nature of the potential FOS present in their tissues are unknown (Table 4).

***Allium* species**	**FOS (mg/g FW)**	**DP[*]**
Bunching onion	-	-
Chinese chive	< 0.1	-
Garlic	3.9[a]	3 ~ 5
Garlic, powder	1.7[c]	3 ~ 5
Leek	0.9[a]	2 ~ 4
Onion, welsh	1.1[a]	3 ~ 5
Onion, white	3.1[a]	3 ~ 5
Onion, yellow	26.3[b]	3 ~ 12
Onion, red	27.1[b]	3 ~ 12
Onion, powder	47.7[c]	3 ~ 5
Shallot	8.5[a]	-

[*] Degree of polymerization
[a] values are total of DP 3 to 5.
[b] values are total of DP 3 to up to 12.
[c] values are total of DP 3 to 5 estimated on dry weight basis

Table 4. The distribution of fructooligosaccharides in edible *Allium* species (Benkeblia et al. 2004, Benkeblia et al. 2005, Campbell et al. 1997).

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