FOOD YEAST SHELLS AND THEIR NUTRITIONAL IMPACT

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ABSTRACT

Shell of food yeasts and their nutritional impact.

The shell (wall and membrane) of food yeast contains a large proportion of carbohydrates and almost all of lipids held in this product. Lipids, strongly imbricated in the wall organization, have a low digestibility (35%).
Two thirds of yeast carbohydrates constitute a fibre that is completely degraded by the intestinal flora. This fibre does not reveal negative effects in the digestibility phenomena.
The energy value of food yeasts can be estimated at 285 kCal/100g 1 200 kJ.

Dry yeasts have made up part of human and animal nourishment for many decades, due to their characteristic nutritional properties: high protein and lysine content, high content of group B vitamins; they are also used for their organoleptic potential.

Yeasts are used principally in two forms, either in a dead and dry state after undergoing sufficient thermal shock for their nutritional content to reach full efficiency, or in autolysate or yeast extract form. In the latter case, the yeast undergoes autolysis which solubilises its cytoplasmic elements, while the cell wall – in the wide sense of the term – remains insoluble. Centrifugation separates the two autolysis fractions; the non-solubilised residue contains essentially the wall and membrane associated with it. We will refer to it under the generic name of shell.

This fraction, which is rich in carbohydrates, is of less importance to us, as the polyosides it contains have an apparently very mediocre nutritional value, due to their atypical nature. It is entirely distinguishable from glycogen, a reserve carbohydrate which is accumulated by the live yeast according to its physiological context. This constituent is rapidly degraded during harvesting and drying technological operations.

Once dead, the yeast essentially only contains support carbohydrate complexes which make up the cell wall. They are equivalent to lignocellulosic elements found in superior plants, but their nature is totally different. We would like to briefly describe them and locate their position in the context of nourishment: their role cannot be overlooked given that they represent between 25 and 35% of the dry matter of food yeast.

LOCATION AND NATURE OF YEAST CARBOHYDRATES

Apart from glycogen, carbohydrates in yeasts are located in cell shells, which represent about 20% of the dry matter of baker's yeast. These shells are made up of an external wall and a cytoplasmic membrane, each element being of a heterogeneous nature, made up of diverse layers of different composition: the wall has a high carbohydrate polymer content while the membrane has a lipo-protidic nature (table I).

In g/100g	Wall	Membrane
Glycans	76,5 (60.0 – 84.5)	16.5 (3.2 – 30.8)
Proteins	9.2 (6.7 – 13.0)	39.5 (26.6 – 49.3)
Lipids	5.7 (2.0 – 8.5)	40.5 (33.3 – 45.6)

Table I: Global characteristics of yeast shells
(after SUOMALAINEN *et al.,* 1973)

At a chemical level, the yeast wall carbohydrates are both complex and atypical, as is demonstrated in one of the most detailed analyses (table II). The originality of the yeast carbohydrates resides in the following principle characteristics:

- cellulose, hemicelluloses, pectins, as well as lignin are not identified amongst the yeast carbohydrates, while these are the classic components of superior plant cell walls.
- the predominant carbohydrates are heteropolymers made up of hexoses: glucose, galactose and mannose. They represent over 80% of the total carbohydrates or 23 g/100 g of yeast.
- oligosaccharides and a specific disaccharide, trehalose, are at minimum levels but are variable depending on the culture conditions;

	In g/100 g	In % of the total
Glucogalactans	9.5	34.4
Galactomannans	8.0	28.9
Glucomannans	5.5	19.9
Trehalose	0.25	0.9
Oligosaccharides	0.6	2.2
Glycogen	3.6	13.0
Reducing sugars	0.25	0.9

Table II: Nature of the carbohydrates of a whey yeast
(aerobic culture) (LIEBRECHT, 1969)

- various elements with a well established nutritive value represent around 15% of the total carbohydrates, that is 4g/100g in the analysis of table II, consisting essentially of glycogen, accompanied by a small quantity of reducing sugars.

In view of this analysis, the yeast contains few elements which enter into the digestible carbohydrates category, that is to say, hydrolysable by the amylases and disaccharides in the digestive system (BERNIER *et al*., 1988). For the most part, they reply to the concept of dietary fibre, to the extent that they are only slightly or not at all digestible in the small intestine, but digestible by intestinal flora.

This conclusion is reinforced by recent analysis techniques. Fibre measurement using the A.O.A.C. method (1990) consists in submitting a delipidated sample to amylase action, then protease action and weighing the final residue deducted from its mineral elements. When applied to a baker's yeast, this technique attains a value of 26,5 g of fibre/100g of dry yeast. This result is to be reconciled with the data in table II, in which the presumed indigestible carbohydrates exceed 23g/100g.

ANALYSIS OF YEAST SHELLS

Global yeast shells (membranes and walls) form a highly organised structure, to such a point that their chemical analysis requires particular procedures in order to obtain a satisfactory result. On the one hand, it is revealed that physical rupture is necessary; this can be carried out by high pressure homogenisation. On the other hand, carbohydrate and lipid dosage requires appropriate modalities. This is why sulphuric hydrolysis is essential (2,5% v/v) in order to hydrolyse the most resistant glycans. Likewise, total lipid extraction can only be obtained by calling upon atypical practices: for example, three successive extractions using saturated butanol, for 36 hours at room temperature plus heating at 70°C for 2 or 3 hours (ADRIAN et FRANGNE, 1976).

Using these procedures, complete analysis of the shells can be obtained, provided that they have firstly been physically broken by a high pressure treatment (table III). In the absence of this preliminary phase, the extraction modalities – even severe – cannot dose the totality of the components contained in these cellular envelopes of a baker's yeast (ADRIAN et FRANGNE, 1976).

In g/100g	Atomised shell	Homogenised then atomised shell
Water	5.9	3.2
Total ashes	2.9	3.7
Crude protein (N X 6,25)	20.1	19.7
Total lipids	23.6	30.3
Total carbohydrates:		
- 3h hydrolysis	31.7	35.5
- 10h hydrolysis	34.9	40.5
Total dosed	87.4	97.4

Table III: Chemical analysis of yeast shells according to their preparation and analytical modalities (ADRIAN et FRANGNE, 1976).

These results bring to light two important facts:

- lipids appear highly imbricated in the glucidic and/or protidic structure, the physical rupture of the structure facilitating their extraction. A complex association between the lipo-protidic membrane and the glucidic wall can be supposed;
- the shell carbohydrates are essentially made up of reducing monosaccharides, given that the dosage based on the reducing capacity (BERTRAND – SOMOGYI) and that which uses reactivity with a phenol in a sulphuric medium (DUBOIS) provide similar values. As for lipids, to obtain complete glycan hydrolysis, preliminary physical breakdown of the shells is essential: a 10h hydrolysis with no preliminary physical stage only gives incomplete results (table III).

This being the case, we can question the digestibility of these shells and the repercussions they can have in terms of nutrition.

DIGESTIBILITY OF YEAST SHELLS

Digestibility has been measured on rats receiving a control ration or a diet containing 20% of yeast shells, homogenised under pressure or unhomogenised, then dried. The physical disintegration treatment does not offer significant digestibility improvement, contrary to observations made during the chemical analyses.

For simplification purposes, the results are displayed in the form of a weighted average of the values recorded with the two types of shells (table IV).

Digestibility percentage	Control diet (2% cellulose)	Diet with 20% shells
Global	96.18	92.07
Nitrogenous	98.75	96.92
Lipidic	82.50	34.41
Glucidic	99.40	89.10

Table IV: Yeast shell digestibility
(ADRIAN et FRANGNE, 1976).

The principle conclusions which can be made are:

- a high global digestibility of the shells (92%) only slightly inferior to that of the control ration;
- remarkable digestibility of nitrogen, close to 97%, indicating that the digestive tract proteases were able to act easily on the proteins included in the wall structure.
- inversely, a lipidic digestibility of only 35%, indicating that the lipids could not be released and hydrolysed sufficiently early during digestive passage to be absorbed by the small intestine;
- finally, a glucidic digestibility of 89%, that is to say, apparently high. This value demonstrates that if the carbohydrates are not digestible in the physiological sense of the term, they are easily usable by the intestinal flora. We can propound that the non-degraded fraction must correspond to that which has the closest association with the lipidic elements and, consequently, less accessible to the glycanases with a microbiological origin.

Carbohydrate fermentability is clearly established in view of caecum biometrics: in the control batch, the weight of the organ is 0,76 g/100 g live, and for animals consuming 20% of shells it reaches 3,27 g, that is, a hypotrophy of around 430%.

NUTRITIONAL IMPACT OF YEAST SHELLS

Let us first recall that at native conformation, the physical structure of these shells constitutes an obstacle to nutritional efficiency of the cellular content. This is why, during drying, the yeasts must undergo a thermal shock which is intense enough to destabilise the wall organisation and allow full usage of the nitrogenous and vitamin potential of the yeast (ADRIAN et FRANGNE, 1970; CHAMPAGNAT et ADRIAN, 1974).

The presence of indigestible shell carbohydrates has no negative consequences on the nutritional efficiency, contrary to what is observed with cereal indigestibility, which hinders the nitrogen and mineral use of the ration. Trials carried out on chickens and rats demonstrate that the yeast ridded of its shells (autolysate) offers the same alimentary efficiency as whole yeast (table V). It must be noted that a superior growth of the animals consuming the autolysate is the consequence of its palatable character, which increases the intake amount (CALET *et al*., 1962).

Overall, if the chemical nature of the yeast wall carbohydrates indicates that they are not absorbable in the small intestine, they are however revealed to be almost totally degradable by the intestinal flora. They can be considered as a “soft” fibre, as opposed to the ballast constituted by the lingo-cellulosic elements of superior plants. They can play a useful ballast role without prejudicing digestibility. This property is exploited in a patent whose object is to use yeast shells as an intestinal ballast. It consists of a shell-rich preparation, containing over 40% of indigestible carbohydrates and less than 1,6% of nucleic acid (PENTILLA et VAARA, 1992).

	Autolysate value in % of the entire yeast
Study on chicken: 4th week: - Weight of the animal - Consumption index* 9th week: - Weight of the animal - Consumption index*	 107.5 99 98 100
Study on rats: - Weight of the animal - Consumption index* - Protidic efficiency factor**	 120 93.5 105
* Dry ingestion/animal's weight gain ** Animal's weight gain/ ingested proteins	

Table 5: Nutritional efficiency of a beer yeast autolysate after elimination of cellular shells: in percentage of the value of the entire dead yeast (after CALET *et al*., 1962)

In practice, the main nutritional consequence linked to the presence of yeast shells must be situated in the energy value domain.

Table VI establishes an estimation of the probable energy value of a yeast, based on its composition and on the digestive use of components situated in the shells (carbohydrates and lipids).

Proteins offer a global digestibility comparable to that of numerous vegetal productions, approximately equal to 88% (CHAMPAGNAT et ADRIAN, 1974); those of the shells even present a superior digestibility (table IV). They can thus be awarded with a ATWATER factor equal to that of many bolted cereals, that is, 3,8 kcal per g.

Component	Content (g/100g)	Digestibility (%)	Atwater factor	Energy supply	
				kcal	kJ
Proteins	50	90	3.8	190	795
Lipids	6	35	9.0	18	75
Carbohydrates:					
- digestible	10	95	4.0	40	165
- indigestible	25	?	1.5 ?	38	160
Energy value:				285	1195
Protidic calories (%)				66	

Lipids, concentrated in the shells, have a digestibility of 35%, which implies that 100g of yeast only contains an average of 2g of lipids endowed with nutritional efficiency.

For the carbohydrates, it can be admitted that 10g are digestible and provide 4 kcal per g. About 25g are not at all or only slightly digestible, but can be easily used by the flora. A fraction must be attacked as of the ileum, thus supplying energetic elements which are absorbable in small proportions. These carbohydrates can be accorded an energy value of 1,5 kcal, by reason of observations of other complex and atypical carbohydrates (BERNIER *et al*., 1988).

In view of these estimations, the energy value of a food yeast is probably situated at around 285 kcal/100g. It is thus a relatively low-energy product, but its protidic interest is highly exceptional, as its nitrogen-origin calories reach 65% of the energy potential, as we have calculated it. (table VI).

From this point of view, food yeasts can be classed at the top of conventional resources. In human alimentation, only skim-milk cheese and low fat fish (cod) have a more pronounced protidic character: eggs and chicken only supply a third of their energy in the form of proteins, full fat milk only a quarter, etc.

In animal production science, yeasts clearly outclass oilseed meal and oilseed crops: only excellent delipidated fish flours can rival with dry yeasts.

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