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Review

# New insight into the role of resistant starch in pig nutrition

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ABSTRACT

In pig nutrition, the analysis of starch is merely focused on assessing total quantity. However, indications suggest that a certain fraction of starch, defined as resistant starch (RS), can escape digestion in the upper gastrointestinal tract therefore passing into the large bowel where can act as fermentative substrate. Nutritionally RS, along with other non-starch polysaccharides and non-digestible oligosaccharides, is regarded as non-digestible carbohydrate. As for humans, the concept of RS has gained increasing attention also in pig nutrition. As a consequence, research to obtain a deeper knowledge on how different RS levels and types may affect energy metabolism, nutrient availability, pig performance and induce positive effects on pigs through fermentation has progressed recently. Therefore, this review comprises updated data on: (i) factors related to the RS content in feed; (ii) systemic effects of RS from various sources in pigs; (iii) aspects associated to the RS fermentation process and role of RS in the pig large intestine; (iv) possible implications of RS on the environmental load of pig facilities. Since the digestibility of starch is compromised in the early period after weaning, the present discussion will be mainly restricted to older animals (especially growing pigs).



**Contents**



*Abbreviations:* DM, dry matter; GIP, glucose-dependent insulinotropic polypeptide; GIT, gastrointestinal tract; GLP-1, glucagon-like peptide-1; N, nitrogen; NDC, non-digestible carbohydrate; RDS, rapidly digestible starch; RS, resistant starch; RS1, resistant starch type 1; RS2, resistant starch type 2; RS3, resistant starch type 3; RS4, resistant starch type 4; RS5, resistant starch type 5; SDS, slowly digestible starch; TS, total starch; VFA, volatile fatty acid.

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## 1. Introduction

Diets for pigs are based on starchy feeds as source of energy and raw cereal grains, along with legume grains and potato starch, constitute the main dietary starch source in pig rations (Sun et al., 2006). Since starch represents a substantial component of diets, characterizing its properties and improving its utilization are important research focuses in pig nutrition. Overall, dietary starch is predominantly digested in the small intestine generating glucose as a final product for absorption (Wiseman, 2006). Dietary starches from different sources are however digested and absorbed at different rates and to different extents depending on three major aspects, which are closely interrelated: (i) physical and chemical characteristics of starch, (ii) degree and type of processing prior to feeding and (iii) animal related factors (Naficov and Beitz, 2007; Giuberti et al., 2014). Hence the rate, extent and site by which starch is degraded will have a range of physiological effects. Such variations can modulate the post-prandial metabolic response, thus having implications on nutrient absorption and pig performance (Regmi et al., 2010; Menoyo et al., 2011; Drew et al., 2012). Considerable information concerning aforementioned factors is largely discussed in technical reviews (Svihus et al., 2005; Bach Knudsen, 2011; Giuberti et al., 2014).

In pigs, as well as in humans, evidences suggest that a certain fraction of starch can escape digestion in the upper gastrointestinal tract (GIT), therefore passing into the colon where can be substrate for fermentation (Williams et al., 2001). This fraction, defined as resistant starch (RS), has received great attention in nutritional science, both in humans (Sajilata et al., 2006; Higgins and Brown, 2013; Birt et al., 2013) and in pigs (Yin et al., 2004; Rideout et al., 2008; Bach Knudsen et al., 2012). Nutritionally RS, along with non-starch polysaccharides and non-digestible oligosaccharides, is regarded as non-digestible carbohydrate (NDC, Table 1). It occurs, basically, in almost all starchy ingredients entering pig diets, but not in a fixed quantity. For instance, raw cereal and legume grains are important natural sources of RS and *in vitro* analysis indicated that they contain from 50 up to 500 g/kg dry matter (DM) of RS (Giuberti et al., 2012a; Torres et al., 2013).

The RS fraction has a contradictory status in pig nutrition. In particular RS has been considered as a negative factor since this fraction may impair energetic efficiency and thus is not always well suited with whole body nutrient use and animal growth (Sun et al., 2006; Rideout et al., 2008; Drew et al., 2012). However, there are ample evidences that RS and other sources of NDC act as potential prebiotic sources (Fuentes-Zaragoza et al., 2011; Bach Knudsen et al., 2012), being a non-digestible dietary component that may affect the host beneficially by selectively stimulating the growth and/or the activity of specific bacteria in the large intestine (Brown et al., 1997). In particular the RS fraction, having similar properties than dietary fibre (Sajilata et al., 2006), can induce positive effects on pigs through fermentation, gut motility, stimulation of gut

**Table 1**
Overview of non-digestible carbohydrates in diets for pigs.[a]

| Category | DP | Common source |
|---|---|---|
| Oligosaccharides | 3–9 | |
| α-Galacto-oligosaccharides | | Soybean meal, peas, rapeseed meal |
| Fructo-oligosaccharides | | Cereals, feed additives |
| Transgalacto-oligosaccharides | | Feed additives, milk products |
| Polysaccharides | ≥10 | |
| Starch | | |
| Physical inaccessible starch | | Seeds, grains, legumes |
| Crystalline resistant granules | | Raw potato, green banana, high amylose cereals |
| Retrograded amylose | | Heat-treated starch products |
| Chemical modified starch | | Modified starches |
| Starch lipid complex | | Amylose containing starch |
| Non-starch polysaccharides (NSP) | | |
| Cell wall NSP | | |
| Cellulose | | Most cereals, legumes, plant cell wall |
| Arabinoxilans | | Barley, wheat, wheat bran, cereal coproducts, rye |
| β-glucans | | Barley, oats, rye |
| Galactans | | Soybean meal, sugar beet pulp |
| Xyloglucans | | Cereals |
| Rhamnogalacturans | | Legume hulls |
| Non-cell wall NSP | | |
| Fructans/inulin | | Rye, rye-coproducts, yam, fibre rich materials |
| Mannans | | Coconut cake, palm cake |
| Pectins | | Fruits, sugar-beet pulp |
| Galactomannans | | Guar gum |

DP, degree of polymerization.

[a] Adapted from Montagne et al. (2003), Bach Knudsen et al. (2012), Evans (2013).

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