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Ontogenic development of intestinal disaccharidases in the precocial rodent *Octodon degus* (Octodontidae)

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Abstract

We studied the ontogeny of the intestinal brush border disaccharidases sucrase and lactase in the precocial rodent *Octodon degus*. Sucrase hydrolyze sugars from plants while lactase hydrolyzes sugars from milk. Enzyme expression varied inversely with dietary changes according to the developmental pattern. All new-born pups had high lactase and low sucrase activities. Also, a negative correlation between sucrase and lactase activity was found, supporting the economic design hypothesis for the intestinal tract. Profiles for development of sucrase expression exhibit some differences among precocial species, and in *O. degus* is correlated with the slower transition from milk to solid food consumption at weaning.

Keywords: Development; Digestion; Disaccharidases; Lactase; Octodon degus; Ontogeny; Precocial; Sucrase

1. Introduction

Early appearance of intestinal hydrolases is an important factor determining the capability of new-born mammals to assimilate ingested nutrients. Among hydrolases, lactase hydrolyzes sugars from milk and appears first in development. Several studies reported that lactase hydrolytic activity in rats is expressed 18 days after conception, reaching a peak 1 week after birth. In contrast, sucrase activity appears 13 days after birth, allowing young animals to make dietary changes from milk to solid food (see Henning, 1985 and references therein). Development of disaccharidase expression appears to be well-matched with ontogenetic changes in consumption of dietary substrates that occur when animals change from maternal milk to solid food. Although some ability to modulate the disaccharidase expression has been elicited by changes in hormone levels (see Menard et al., 1981), no expression of sucrase may be induced by changes in diet composition during the early postnatal period (Jost et al., 1998). Ontogenetic changes in enzyme expression seem to be a genetic adaptation to dietary changes that occur at weaning (see also Moog, 1981; Yeh and Holt, 1986; Crisp et al., 1989; Dvorak et al., 2000).

The expression of enzyme activity during development has been extensively studied in placental mammals, particularly on altricial mammals (see Henning, 1981; Weaver et al., 1988; Sabat and Bozinovic, 2000). For example, *Acomys cahirinus* a precocial species close relative of the genus *Rattus*, has very low levels of sucrase activity during the first 2 weeks, showing an increase during the second and third weeks to adult levels

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(Lamers et al., 1985). Also in guinea pigs (*Cavia porcellus*), a rise in lactase activity is observed in naturally fed animals in the first week after birth (Weaver et al., 1991). However, studies in precocial species have been centered on domestic and laboratory animals, but not on feral species (e.g. Green and Hardorn, 1977; Lamers et al., 1985). This study was conducted to describe the developmental pattern of intestinal lactase and sucrase in the precocial degu (*Octodon degus*, Rodentia: Octodontidae). The main objective was to determine possible interspecific differences of the pattern of disaccharidase expression, and to correlate them with the development pattern.

Octodon degus is a precocial rodent with a 3-month-long gestation period, born with open eyes and well developed fur and teeth (Mann, 1978). Degus are mother-dependent during the first month of life and begin to consume exclusively solid food only 3 weeks after birth, although lactation may last an additional month. In addition, *O. degus* exhibits a highly thermal dependence on the mother (Veloso, 1997). During the first 3 weeks, pups cannot regulate their body temperature being unable to survive without the mother (Veloso, 1997).

We expect that if the small intestine function develops as an adaptation to dietary substrates, the activity of sucrase should be absent in newborn specimens, as observed in altricial species. Associated with this, sucrase activity should increase with age, with lactase activity decreasing over time according with the transition from maternal to autonomous feeding. Alternatively, if precociality determines the development of intestinal hydrolases, then, constant activity of both enzymes at birth are to be expected, with a subsequent increase of sucrase over time.

2. Materials and methods

Pregnant females reared from a lab stock were maintained in individual cages with water ad libitum. They were fed with commercial pellet chow, under L:D 12:12 h and at 24 ± 2 °C. A total of 21 pups were obtained that were reared with their mother until sampling. Animals were weighed (± 0.05 g) and killed by decapitation at different stages of development, from birth to day 90. Most pups were killed in the first month because the focus of this study was the lactation period. After animals had been killed, their digestive tracts were excised, weighed (± 0.005 g) and washed with 0.9% NaCl. The small intestine was frozen in liquid nitrogen for subsequent enzyme determinations. The whole intestines were thawed, and homogenized (30 s in an Ultra Turrax T25 homogenizer at maximum setting) in 20 vol. of 0.9% NaCl solution. The activities of sucrase (EC 3.4.11.2) and lactase (EC 3.2.1.23) were determined according to the method of Dahlqvist (1964). Briefly, tissue homogenates (100 μl), were incubated at 37 °C with 100 μl of 56 mmol l^{-1} sugar (sucrose or lactose) dissolved in 0.1 mol l^{-1} maleate/NaOH buffer (pH 6.5). After 10 min of incubation, reactions were stopped by adding 3 ml of a stop/developing Trinder solution [one bottle of glucose Trinder 500 reagent (Sigma Chem. Co.) in 250 ml 0.1 mol l^{-1} Tris–HCl (pH 7) plus 250 ml of 0.5 NaH_2PO_4, pH 7]. After 18 min at 20 °C absorbance was measured at 505 nm with a spectrophotometer. Enzyme activities are presented as standardized hydrolytic activity (IU g^{-1} wet tissue, where IU = μmol hydrolyzed min^{-1}). A Kruskal–Wallis ANOVA was used to determine specific differences in hydrolytic activity at the first month of life. A posteriori Tukey-type test was used. In addition, in order to determine the possible relationship between disaccharidase activities, a Pearson correlation was performed between sucrase and lactase activity.

3. Results

Sucrase activity was found in all newborn pups of *O. degus* (Fig. 1). Moreover, significant differences in sucrase activity were observed during the first month ($H_{5,21} = 17.41$, $P = 0.004$). Sucrase activity exhibited a detectable increase at day 16 and continued increasing to adult activity levels after weaning (Fig. 1). Contrarily, lactase activity showed a high and constant activity during the first 16 days. At weaning (day 30) it started to decline, until adult stage, near day 90 ($H_{5,21} = 13.91$, $P = 0.02$, Fig. 1). A strong negative correlation ($r = -0.83$, $P < 0.001$) was observed between lactase and sucrase activity.

4. Discussion

The development profile of disaccharidase expression in *Octodon degus* seems to be well correlated with feeding and nutritional history of growing pups. *O. degus* start consuming solid food

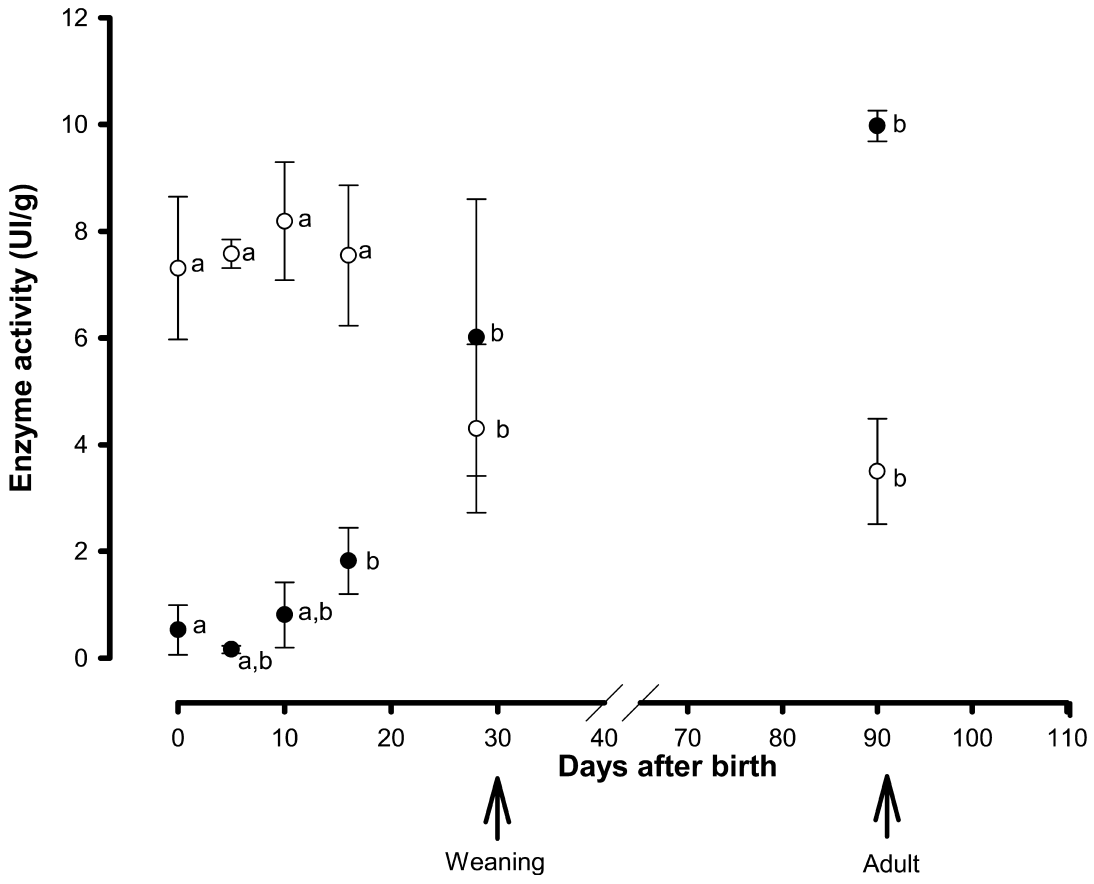

Fig. 1. Development of disaccharidase activities (IU g^{-1} wet tissue) in the intestinal homogenate of *Octodon degus.* Note that both disaccharidases, sucrase (closed symbols) and lactase (open symbols) were present in newborn individuals. Means with different letters are significantly different, $P<0.05$.

early in development (Mann, 1978), a fact that is reflected in minimal levels of sucrase activity in the newborn. This may be the result of consumption of solid food and probably coprophagy (see Kenagy et al., 1999). Unlike altricial mammals that show a sudden peak of sucrase expression at weaning (Kojima et al., 1998; Jost et al., 1998), sucrase activity in *O. degus* shows a continuous increase during the lactation period. Also, within precocial species developmental profiles of sucrase expression are variable. In general *O. degus* shows a slow increment of sucrase activity compared with other species (Lamers et al., 1985; Kojima et al., 1998; Jost et al., 1998; Weaver et al., 1991). Also, compared to other precocial species, in *O. degus* the adult levels are reached more slowly, probably near the sixth week of life (Fig. 1). This pattern is in accordance with the slow transition from milk to solid food consumption exhibited by this species.

Developmental expression of lactase activity in *O. degus* was slightly different from other altricial and precocial species. In guinea pigs, in spite of a decrease in milk lactose concentrations, a rise in lactase activity is observed in the first week (Weaver et al., 1991). In degus, such increase in lactase activity was absent and a continuous decrease in lactase activity is apparent, as already seen in *A. cahirinus* (Lamers et al., 1985) and in rat (Fig. 1). In altricial mammals different profiles for lactase expression have been documented. Freund et al. (1991) reported a progressive decrease in lactase activity from birth to 24-month-old rats. However, Zhang et al. (1997) found in rats an increase in lactase activity in the first day of life, and Lamers et al. (1985) noted the same increment

in the first days of life. Although differences in the profiles of lactase expression may be related to the nutritional stage and differences of the composition of experimental diets (see Schwartz and Heird, 1994; Burrin et al., 1994), developmental expression of lactase in *O. degus* is probably due to a fixed genetic program, as in other mammals (Zhang et al., 1998), and several studies have shown that prolonged suckling delays, but does not prevent, the usual decrease in lactase activity (see Henning, 1985). Along this vein, Veloso (1997) reported that chemical composition of milk varies during lactation in *O. degus*. During the first week, sugars (probably lactose), make up more than 12% of total solids and then decline to near 4% at the fourth week, which contrast with the constancy of lactase activity shown by *O. degus* during this period. These facts suggest the existence of a fixed genetic program controlling the lactase expression in degus.

It is clear that profile of disaccharidase expression in *O. degus* approaches more closely that found in precocial than altricial species. However, slight differences in disaccharidase profiles suggest that development of intestinal enzymes in *O. degus* may not be well matched with the precocial pattern of development, responding to specific differences in the timing of transition from maternal to completely autonomous nutrition. Furthermore, the negative correlation between sucrase and lactase activity supports the hypothesis of economic design of the intestinal tract (see Diamond, 1991; Hume, 1998). At birth, when mammals consume mainly milk, sucrase expression should be repressed. The contrary is true for lactase, which is rendered unnecessary when pups feed exclusively on solids. Further studies are needed to know whether or not dietary chemical composition may modulate the timing of expression of digestive enzymes in this precocial rodent.

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