

Consumption patterns: A proposed model for measurement of solution palatability in pigs¹

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ABSTRACT: In animal production, the palatability of feeds or solutions has typically been inferred from measurements of preference or acceptance. However, laboratory studies in rats have demonstrated that palatability quantified through the analysis of the microstructure of licking can dissociate from simple measures of consumption. The aim of this study was to evaluate palatability in pigs by using consumption patterns. Pigs ($n = 24$) were exposed (in pairs, with video recording) to different sucrose solutions (0.5, 1, 2, 4, 8, 16, and 32%) over 7 consecutive 10-min tests (1 concentration/d). Total consumption, number of consumption approaches (A), and real consumption time (RCT) were mea-

sured. Palatability was estimated through consumption pattern (RCT/A), analogous to the licks/bout measure used in rats. Data was analyzed by sucrose concentration. Spearman correlation coefficients were estimated between the logarithm of sucrose concentration and total consumption, A, RCT, and RCT/A. Total consumption and RCT showed inverted U functions relative to sucrose concentration. Consumption pattern (RCT/A) presented a dose effect ($P < 0.005$) and positive correlations with sucrose concentration ($R = 0.23$, $P = 0.034$). As with rats, consumption pattern could represent an interesting and novel measure of feeding behavior, reflecting palatability in pigs.

Key words: palatability, pigs, sucrose solutions, welfare

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INTRODUCTION

The assessment of palatability or hedonic reactions during animals' intake has been typically based on the preference or acceptance of feeds or solutions. However, these measures are also influenced by components of the feeding situation beyond palatability (Forbes, 2010). Laboratory studies in rats have demonstrated that palatability quantified through the analysis of licking microstructure (or orofacial responses) can dissociate from simple measures of consumption. For example, consumption of sucrose

is highest at moderate concentrations, whereas lick cluster size (mean number of licks per bout of drinking) increases monotonically with sucrose concentration (Davis and Smith, 1992; Dwyer, 2012). This technique can also determine changes in palatability after flavor preference and aversion learning (Dwyer, 2009, 2012). In addition, drug treatments thought to influence hedonic responses in humans also influence lick cluster size (Higgs and Cooper, 1998). This pattern of evidence strongly supports the idea that lick cluster size is a valid index of hedonic reactions and solution palatability in rodents.

Estimating the hedonic reactions in productive animals such as pigs could be of particular interest for their nutrition and management—both through evaluating/improving welfare and through helping to maximize intake. For example, a reduction in hedonic reactions to normally palatable foods could be used as an indicator of poor welfare (negative emotional state) and decreased production capacity; this state poten-

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tially could be remediated by reformulation of diets to enhance positive hedonic reactions. Investigating hedonic reactions also provides evidence concerning the mechanism by which diet manipulations impact overall consumption, for example by identifying whether otherwise beneficial inclusions might be rejected on the basis of low palatability. Despite recent interest in pigs' feeding behavior (Figuroa et al., 2012), there are currently no measures that deliver direct estimates of pigs' hedonic reactions during intake. The present study aimed to compare consumption patterns (analogous to the licks/bout measure used in rats) with other feeding behavior measures such as total consumption as indicators of the palatability of sucrose solutions in pigs.

MATERIALS AND METHODS

The experiment was conducted at the weaning unit of the Universitat Autònoma de Barcelona (UAB; Barcelona, Spain) pig facilities, and pigs returned to commercial production within the UAB facilities after the experiment. Experimental procedures were approved by Ethical Committee on Animal Experimentation of the UAB (CEAAH 1406).

A total of 40 male and female 42-d-old pigs ([Large White \times Landrace] \times Pietrain), weighing 9.2 ± 0.9 kg were used. Pigs were weaned at 28 d of life in a weaning room equipped with automatic, forced ventilation and a slatted floor. They were ad libitum fed with a commercial powder feed except for 1 h before and after each test. In the second week after weaning (35–41 d old), pigs were acclimated to the experimental conditions by being offered a dish of water for 1 h each morning (0900 to 1000 h) at the front of each pen. At the beginning of the third postweaning week (42 d old), 24 pigs were randomly selected, weighed, and placed into experimental testing pens (1.6 m^2 in floor area). They were exposed in pairs ($n = 12$) to different sucrose solutions (0.5, 1, 2, 4, 8, 16, and 32%) over 7 consecutive 10-min tests (1 concentration/d). Half of the pig pairs were tested with increasing sucrose concentrations (0.5 to 32%) and the rest with decreasing concentrations (32 to 0.5%). Pigs were video recorded (4 video cameras, IR Outdoor Cameras 700tvl 1/3 cmos Sony; SENKO SA, Santiago, Chile) during the testing to allow behavioral sampling over a period of 10 min per session.

Total consumption, number of consumption approaches (**A**), and real consumption time (**RCT**) were measured. Total consumption was measured by weighing dishes at the beginning and end of each test. Consumption approaches and RCT were assessed from the video recordings (RCT = total time at the feeder; A = number of times the feeder was approached with a consumption result), by focal continuous sampling over

the 10-min test period. Although the overall analysis presented here focuses on the whole 10-min consumption period, we also performed additional analyses on the first (1–5 min) and second (6–10 min) subperiods to examine how parameters might change across time.

Consumption, A, RCT, and RCT/A were analyzed with ANOVA using the MIXED procedure of the statistical package SAS (SAS Inst. Inc., Cary, NC) with sucrose concentration as a repeated measure (0.5, 1, 2, 4, 8, 16, and 32%) and test order (increasing or decreasing concentration) as a between-subject factor. The experimental unit was the pig pair with results expressed as the average of both pigs' data. Spearman correlation coefficients were used to evaluate monotonic relationships between the logarithm of sucrose concentration and total consumption, A, RCT, and RCT/A by using the CORR procedure of SAS. Alpha was set at 0.05 for all analyses.

RESULTS

Total consumption, A, and RCT were affected by the sucrose concentrations during the total experimental time ($P = 0.012$, $P = 0.028$, and $P = 0.028$, respectively). These parameters showed inverted U functions relative to sucrose concentration with the highest values at intermediate levels (Fig. 1). Test order did not affect any parameter ($P > 0.05$). However, an interaction between test order and sucrose concentration appears on A ($P = 0.004$) and RCT/A ($P = 0.008$). There were no significant Spearman correlations between sucrose concentrations and consumption ($R < 0.01$, $P = 0.975$), RCT ($R = 0.07$, $P = 0.516$), or A ($R = -0.07$, $P = 0.518$). Analysis of variance also revealed that RCT/A was influenced by sucrose concentration ($P = 0.005$). Real consumption time/A showed significant Spearman correlations with sucrose concentration ($R = 0.23$, $P = 0.033$), indicating that unlike the other measures, RCT/A does show a monotonic increase with sucrose concentration.

DISCUSSION

Pigs displayed inverted U functions between intake and sucrose concentration with higher consumption observed at intermediate concentrations. However, for consumption patterns (i.e., RCT/A), adapted from lick cluster size used in rats (Dwyer, 2012) and similar to what Clouard et al. (2014) described as the "duration of the drinking episodes," the highest values were found as sucrose concentration increased until a point where it seem to reach to a plateau. That is, pigs spent longer periods in each feeder approach as sucrose concentration increased. These results are consistent with prior rodent work, where mean lick cluster size

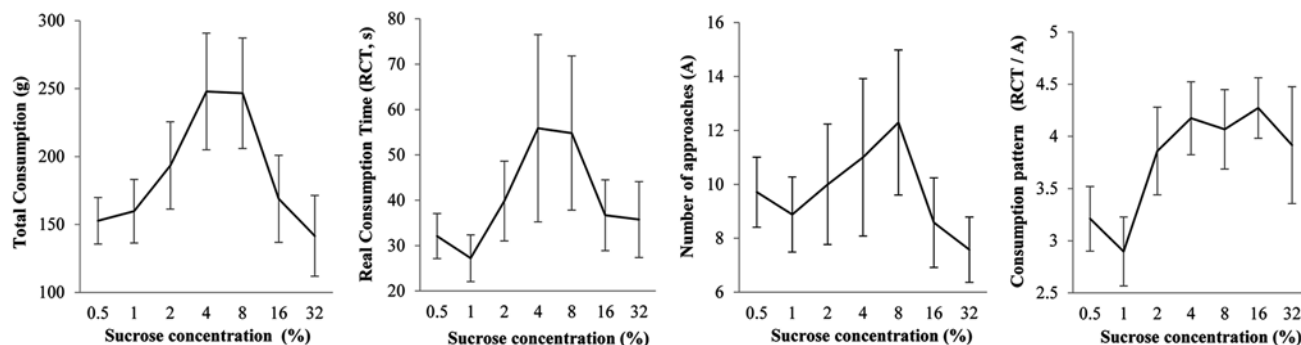


Figure 1. Means (\pm SEM) of total consumption (g), real consumption time (RCT), number of total consumption approaches (A), and consumption pattern (RCT/A) over 10 min from pigs ($n = 12$) exposed to different sucrose concentrations.

increases monotonically with the hedonic value of a solution (e.g., the sweet taste of sucrose; Davis and Smith, 1992; Dwyer, 2012). Therefore, the present results suggest that consumption patterns during intake provide a more direct measure about pigs' hedonic reactions to sensory cues, such as sweet taste, than do simple intake measures such as overall consumption. That said, it should be acknowledged that the rate of increase in RCT/A with concentration was stopped at the highest concentrations, reaching a plateau. An additional analysis suggests that RCT/A values did not correlate with concentration when the final (6–10 min) of the test period was considered alone. These observations may suggest that the sensitivity of this method might be attenuated with very palatable solutions or as exposure is extended (possibly due to ceiling effects in palatability or satiation). Therefore, further work will be required to determine the ideal parameters for consumption pattern analysis in pigs and establish if there are particular boundary conditions for this technique.

Despite these caveats, the clear dissociation between total intake and RCT/A measures in response to changes in sucrose concentration demonstrates the limitations of using simple consumption measures as an indication of hedonic responses or palatability. As a result, total intake (or even the preferences) will not necessarily reflect more palatable diets and may limit the reliability of any recommendations regarding optimal feed inclusions. In short, the current study suggests that the analysis of consumption patterns could represent an interesting and novel measure in feeding behavior reflecting palatability in pigs. Moreover, the fact that changes in the internal state of rodents (e.g.,

through learning or stress; Dwyer, 2012) can selectively influence consumption patterns also raises the possibility that the analysis of feeding consumption patterns in pigs may offer a particularly valuable tool for identification of hedonic dysfunctions or welfare problems in animals kept in production systems.

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