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DEVELOPMENT OF A SENSOR-BASED MONITORING SYSTEM FOR THE ANALYSIS OF THE RELATIONSHIP BETWEEN FEEDING BEHAVIOUR AND SUB CLINICAL METABOLIC DISORDERS IN DAIRY COWS

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Abstract

The use of sensor–based systems in animal husbandry is an objective way of better controlling and evaluating animal behaviour and reactions and their alteration in time under the prevailing husbandry system. Animal reactions are possible indicators for animal health or can be used as decision guidance in production processes. Animal monitoring systems provide information about animal health contributes to economy and animal welfare. Recent animal husbandry systems demand intensive physiological performance, leading to an enormous sensibility of the organism. Milk secretion in the dairy cow has a high metabolic priority and is clearly maintained at the cost of other reproductive and metabolic processes. Most common diseases are reproductive disorders, mastitis, metabolic disorders (such as ketosis) and lameness. Health problems in dairy cows are important for farmers because they result in losses of milk yield, lead to treatment costs and detrimental to animal welfare. These problems are often results of insufficient energy intake. Numerous studies have shown a strong correlation between dry matter intake (DMI) post partum and incidences of clinical disorders. Regarding these correlations, the project "feedwatch" analyses the feeding behaviour of dairy cows (duration of feed intake, frequency of feed intake) during the transition period and early lactation. Based on previous studies a new monitoring system will be established, focussing on feeding behaviour and its alteration in time by individual identification. The aim of the study is to build new models in order to get an early-alert-system to maintain animal health and animal well-being.

Keywords: Dairy cows, feeding behaviour, sensor-based monitoring system, sub clinical metabolic disorders, animal welfare

Introduction

Sensor–based systems in animal husbandry can be used to control and evaluate animal behaviour and reactions and their alteration in time under the prevailing husbandry system. Animal reactions are possible indicators for animal health. They also can be used as decision guidance in production processes. Animal monitoring systems provide information about animal health in order to increase the economic benefit and animal welfare.

Recent animal husbandry systems demand intensive physiological strains, which lead to an enormous sensibility of the organism. Milk secretion in dairy cows has a high metabolic priority and is clearly maintained at the cost of other reproductive and metabolic processes. Most common diseases are reproductive disorders, mastitis, metabolic disorders (such as ketosis) and lameness. While clinical disorders cause obvious anatomic and/or physiologic changes, sub clinical disorders cannot be detected without laboratory methods. Therefore, the detection of sub clinical diseases is expensive and often requires invasive methods. Consequences of sub clinical disorders occur in decreasing milk yield, increasing treatment costs and restricted animal welfare.

These problems are often results of an insufficient energy intake. Numerous studies have shown a strong correlation between dry matter intake (DMI) post partum and incidences of clinical disorders. For example, incidence of ketosis, metritis, retained placenta and dislocatio abomasum are associated with a reduction of DMI (*Azizi*, 2008). *Engelhard* (2005) analyzed the development of milk production and feed intake from 1996 to 2003 by using individual automatic feeder. He reported that the milk yield during the first month of lactation increased from 37.4 kg/d in 1996 to 42.2 kg/d in 2003. This 13% increase in milk yield stood in contrast to a mere 6% increase in feed intake (19.4 kg DM/d in 1996 to 20.5 kg DM/d in 2003). This lag between energy output from milk yield and energy input from feed intake leads to a negative energy balance.

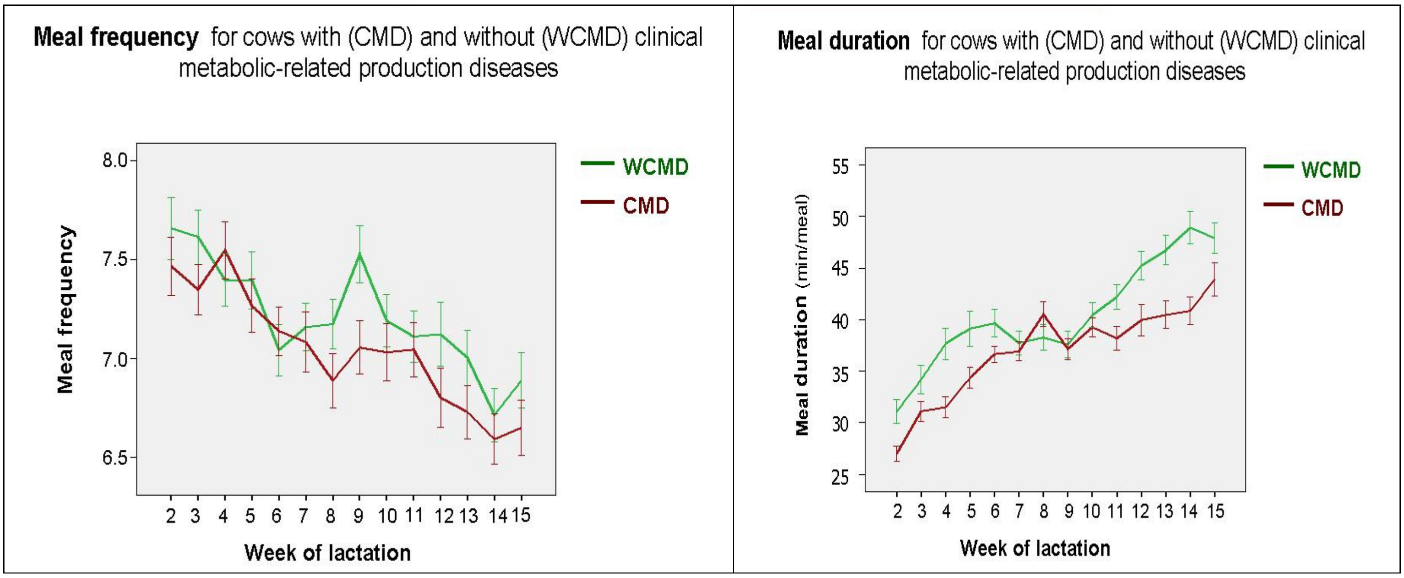
The transition period extends from the last 3 weeks of gestation through the first 3 weeks of lactation (*Grummer*, 1995; *Drackley*, 1999) and is critically important to health, production, and profitability of dairy cows (*Drackley*, 1999).Nutrition and management programs during this period directly affect the incidence of postpartum disorders, milk production and reproduction in the subsequent lactation. More than 80% of all health disorders occur during this time. One of the major challenges faced by the cow at this time is obtaining sufficient energy to support the onset of lactation, especially while feed intake tends to be suppressed around the time of calving (*Drackley,* 1999, cited by *Azizi*, 2008). *Fleischer et al.* (2001) studied the incidence rate of postpartum disorders in high-producing dairy cows.

They found that post partum transit period is associated with an increased risk for many diseases and disorders. Therefore, monitoring of animal behaviour during these periods might be very useful to detect cows at risk for health disorders. Information about changes in feeding behaviour and reduction of DMI can also be helpful to avoid invasive methods and to detect sub clinical disorders at a very early stage.

Background

Factors affecting and regulating the feed intake of lactating dairy cows are numerous and complex. Therefore, the determination of factors affecting DMI and quantification of their effects are important for developing new feeding strategies during the transition period (*Hayirli et al*., 2002). The analysis of feeding behaviour may help to explain the physiological mechanisms of feed intake regulation. This is also important for the optimization of feed intake in cattle, especially during periods in which feed intake becomes a major limiting factor for production (e.g., in early lactation) (*Senn et al*., 1995).

Previous studies showed a correlation between characteristics of short-time feeding behaviour and clinical metabolic-related production diseases (*Azizi* 2008). *Figure 1* shows meal frequency, meal duration, daily mealtime and daily dry matter intake for cows with and without clinical metabolic-related production diseases.



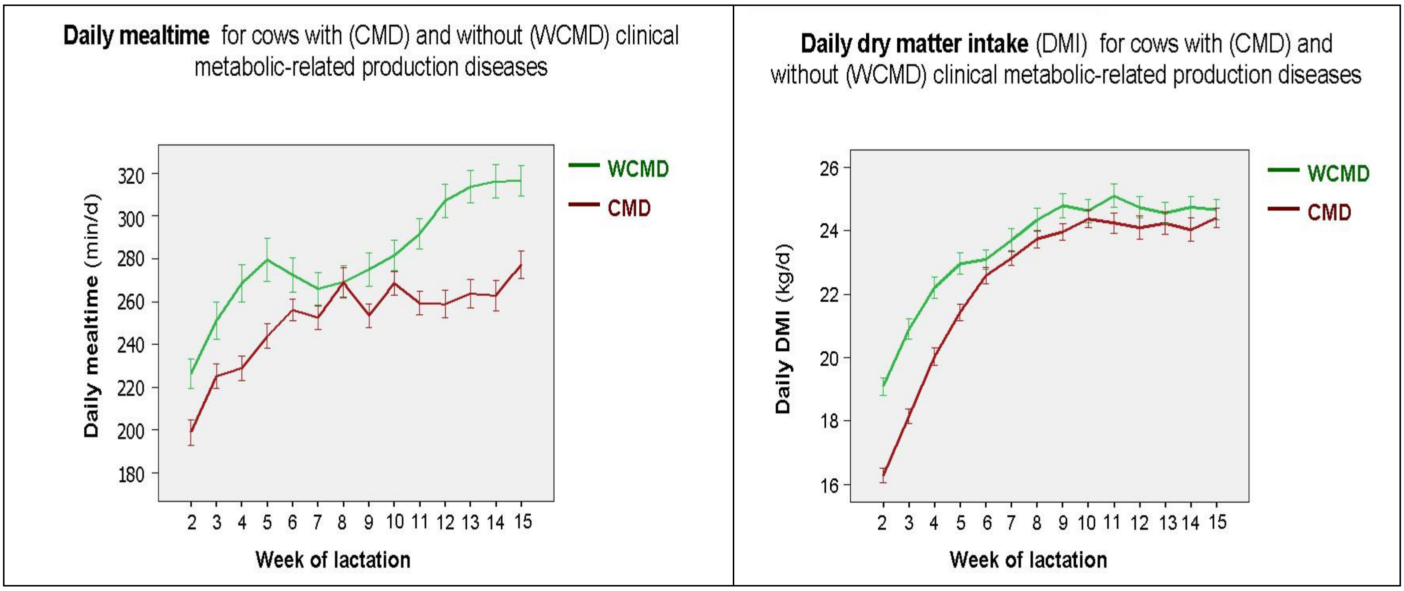


***Figure 1*. Meal frequency, meal duration, daily mealtime and daily dry matter intake for cows with / without clinical metabolic-related production diseases in dependency of lactation week**

The time spent eating, and the pattern of meals, can obviously have important effects on the total daily intake of dairy cattle (*Grant and Albright*, 2000). For that reason, many studies in dairy nutrition and management have focussed not only on changes in intake, but also on changes in feeding behaviour. *Azizi* (2008) showed a high correlation between meal duration (min/meal) and meal size (kg/meal) (*Figure 2*). Average daily intake is the result of the number of feeding bouts per day and the size of those bouts. Cows typically divide their feeding time into a series of meals separated by non-feeding intervals. *Tolkamp et al.* (2000) have suggested that the meal, rather than an individual feeding event, is a more biologically relevant unit to describe animal feeding behaviour. The meal criterion has been defined as the longest non-feeding interval being still considered as an interval within a meal. The measurements typically used include meal size, frequency, and duration. The meal criterion is the log interval at which two curves intersect (frequency distribution of the log-transformed intervals fitted with a mixture of two normal distributions).

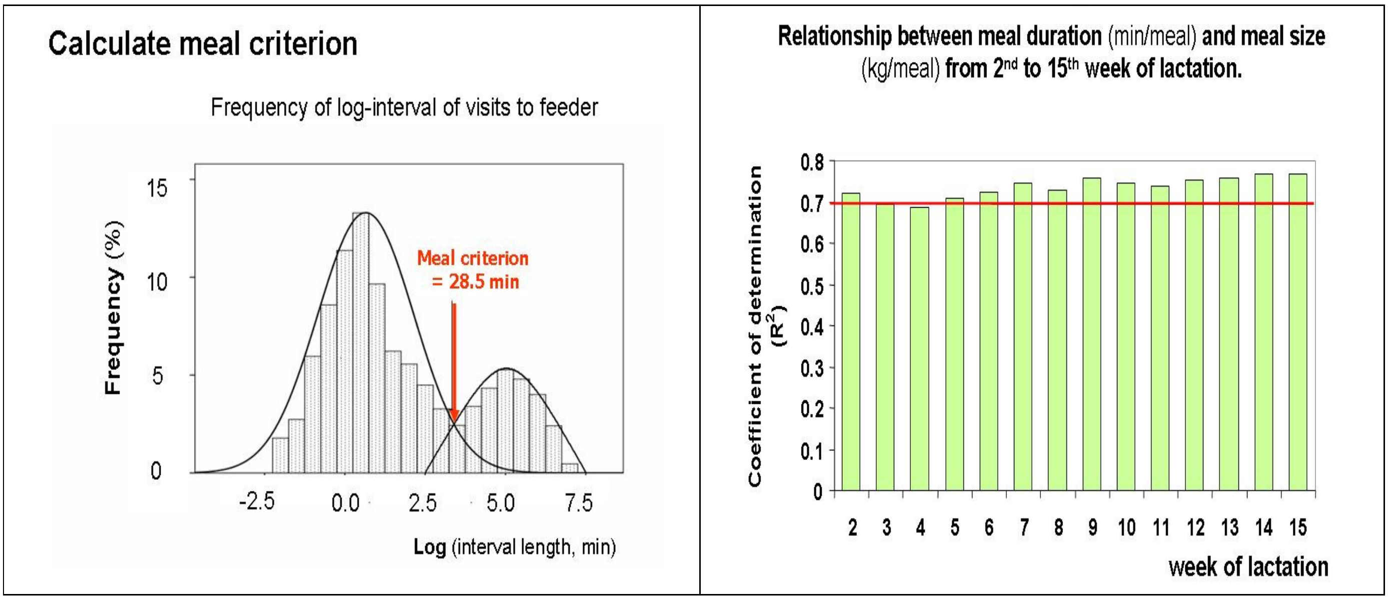


Figure 2. **Definition of meal criterion and relationship between meal duration and meal size**

Regarding to these results, the following questions occur:

1. Which feeding behaviour characteristics are relevant to estimate feed intake?
2. Can feeding behaviour characteristics be used to predict the total feed intake?
3. Do metabolic-related production diseases *(particularly subclinical)* affect feeding behaviour characteristics?

Realisation: Project "feedwatch"

The project "feedwatch" analyzes the feeding behaviour of dairy cows (duration of feed intake, frequency of feed intake) during the transition period and early lactation under on-farm conditions. Based on studies mentioned above, a technical and applicable monitoring system will be established, focussing on feeding behaviour and its alteration in time by individual identification. The aim of the study is to build new models for an early-alert-system to maintain animal health and animal well-being.

The project is divided into the test phase, including validation, and the main phase. The test phase implies the installation of six identification systems in a separated area of the stable with heifers (max. 6 cows), observed via video control. After the evaluation of the ID-System, the main phase will take place by the installation of a total of 42 ID-Systems. The whole measuring period starts at week 8 ante partum and finishes at week 6 post partum.

For this reason, four groups will be established:

- Fresh cows (cows from d 1 p.p. till d 10 p.p.)
- Early lactation cows (cows from d 11 p.p. till d 180 p.p.)
- Lactating cows (cows from d 181 p.p. till d 307 p.p.)
- Transition period cows (cows from d 55 a.p. till partus)

Based on the results of the main phase, the system will be upgraded and advanced. In the following the ID-System and the video control system as well as first results of the test phase are described.

Monitoring system

Feeding behaviour of lactating dairy cows fed ad libitum can be measured in different ways. The system best suitable for our objective is a number of automatic feeders with an identification system which can handle and record data from a large number of cows in a free-stall housing situation for long periods (*Figure 3*). Using the current RFID-technology, our system consists of a transmitter-receiver-set at each feeding alley (Duräumat). Those sets match the individual cow-ID-system. The required data of feeding visits and the time spent at the feeding alley for each cow can be recorded by a well-established software program (dairy plan 5.0). After proceeding the data are transferred into a data base (MS Access) to analyze the behaviour patterns using statistical methods.

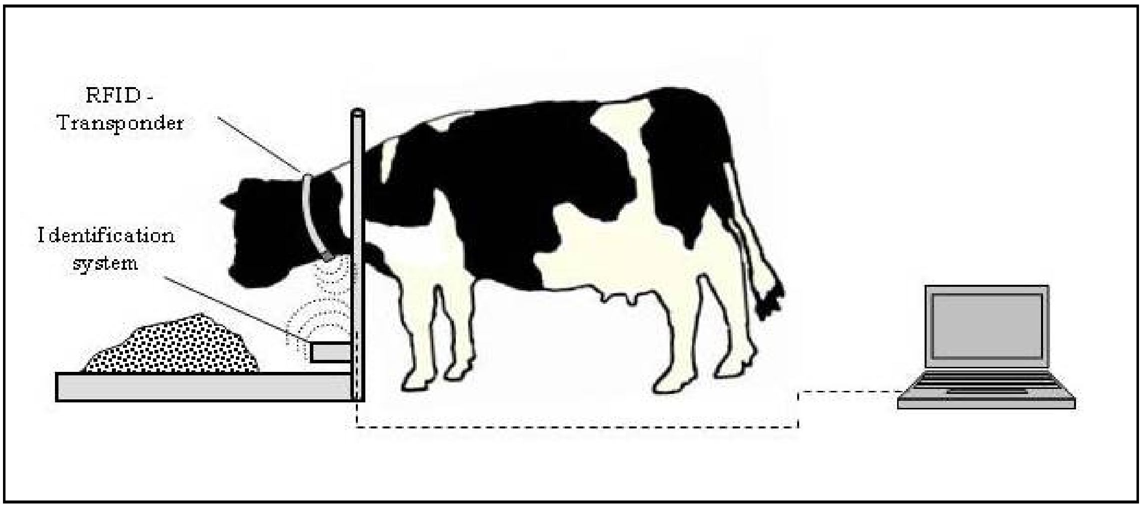


Figure 3. Draft of the measurement setup in the test area

Video control

In order to validate the identification system, a separated area (calving cows with ID and additionally marked with colour) with six systems are observed via video control (two cameras placed in two directions focussing the feeding alley from both sides) at different times during feeding. Before starting recording, time levelling hast to be simultaneous to the measuring protocol of the ID-system. The following figure (*Figure 4*) shows the position of both cameras placed approx. 3 meters above ground.

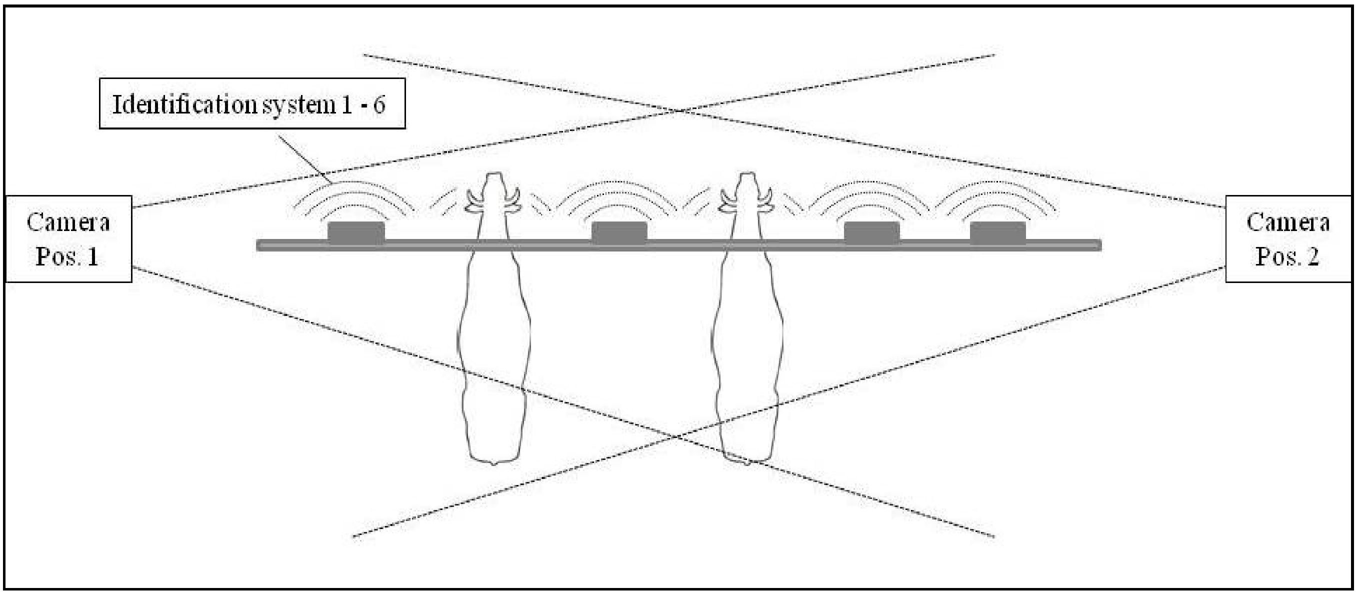


***Figure 4.* Position of the two cameras**

Data Analysis

The software program Dairy plan 5.0 (dp5) provides a measuring protocol with the following data: Date, Animal ID, Feeder number, Final time of contact, Number of visits, Duration of visits.

***Table 1*. Abstract of the measuring protocol (dp5)**

Date	End time	Feeder No.	Animal ID	Visit No.	Duration
13.05.2009	14:21.30	4	195	1	0:22
13.05.2009	14:22.21	4	195	1	0:17
13.05.2009	15:48.00	1	195	2	0:31
13.05.2009	15:49.54	1	195	2	0:30
...	...	...	...	...	...
13.05.2009	17:00.13	4	195	3	0:25
...	...	...	...	...	...

The software program dp5 records the contact of the animal (with RFID transponder) with identification system. If the interval between two contacts is less than 2 minutes, it will be defined as one visit (*Table 1.,* Visit No.). Using this approach it is possible to include the cow's individual behaviour e. g. shaking the head or removing the head from the headlock to scrap its back. If the interval between the single contacts is about xxx seconds or the cow changes from one to another feeder, a new visit is recorded (*Table 1*). To validate the system, this protocol has to be adjusted to the video recordings.

Results

First results of the measurements (validation of the system during the test run and the accuracy of the identification system) can be described as follows:

Validation of the identification system

The comparison of the identification system's measuring protocol with the video recordings showed satisfactory results. Visits of the cows were registered simultaneously by the identification system and the video control. No interferences between the different adjoining identification systems or the different RFID transponders were recognized. The criteria for system evaluation are:

$$Sensitivity = \frac{number\ of\ true\ positives}{number\ of\ true\ positives + number\ of\ false\ negatives}$$

$$Specificity = \frac{number\ of\ true\ negatives}{number\ of\ true\ negatives + number\ of\ false\ negatives}$$

$$Error\ rate = \frac{number\ of\ errors}{number\ of\ examples}$$

Video control

The video control system represents a useful ad-on to the simulcast-observation and a good possibility to validate the animal monitoring system. But it is not the most favourable option for a permanent online-observation. The quality of camera recordings is not sufficient in order to detect the animals by their individual transponder number. Therefore, additional colour marks were added for an absolutely certain identification. Thus the camera observation is not suitable for a large animal group.

Data analysis

The first step of the analysis is to bring the data into an analyzable format. Therefore, all contacts of each cow have to be classified to the discrete visits. This is done by the measuring software dp5. The next step is to add the duration of the single contacts within a visit, which has to be done manually (i.e. MS Excel).

Discussion

The aim of the project "feedwatch" is to establish a technical and applicable monitoring system focussing on the feeding behaviour of dairy cows (duration of feed intake, frequency of feed intake) during the transition period and early lactation. Based on previous studies the importance of an early-alert system in order to maintain animal health and well-being is clear. The technical implementation of an identification system in a housing system without rebuilding the existing infrastructure is the challenge of this project. There are many possibilities to measure feeding behaviour of farm animals, such as electronic feeders (with a scale), but all of them are linked with replacements in the existing housing system and high investments. Measuring the feeding behaviour only by means of individual identification at the feeder could be a better economic answer to this problem.

Our first measurements showed good results with regard to the accuracy of the identification system as represented via the combination of the video control and the monitoring system. Further measurement has to be done to strengthen these results and to enhance the system. At this moment new identification systems are embedded (all up 42 systems) with the aim to record up to 100 animals from week 8 ante partum to week 6 post partum. Acting on the assumption from these data, new models and analyzing methods will be developed in order to detect changes in feeding behaviour of each individual.

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