



FIG. 2. Growth of *M. thermautotrophicus* in a fed-batch reactor at high gassing rate. The organism was cultured in 2.5 liters of mineral medium at a constant gassing rate of 428 ml min⁻¹ with 80% H₂-20% CO₂ (vol/vol). Measurements started ($t = 0$ h) 8 h after adjustment of the gassing rate. Panels A to C and symbols are as described in the legend to Fig. 1.

dissolved hydrogen partial pressure steadily decreased to become as low as 1 kPa. Before that time, the hydrogen consumption rate had become constant (84 ml min⁻¹), and 98% of the gas ended up in methane. When the p_{H_2} had reached the minimum at $t = 10$ h, the optical density increased linearly over time. This period is denoted as the linear phase. Apparently, growth now became limited by the H₂ supply. To test this, the organism was grown at a higher gassing rate (428 ml min⁻¹). The same growth behavior was found (Fig. 2A). Quite remarkably, p_{H_2} did not drop to low values during the linear growth stage, but it was maintained as high as 29 kPa. Again, the hydrogen consumption rate became constant ($v_{H_2} = 275$ ml min⁻¹), but the gas was only partly utilized. Further experiments showed that the p_{H_2} values could be manipulated by the H₂-CO₂ gassing regimen (Table 3). Depending on the hydro-

gen mass transfer characteristics, i.e., gassing rate/culture volume ratio and mixing intensity (number of impellers), steady p_{H_2} values were obtained during the linear growth phase that ranged between 1 and 59 kPa. Linear growth could proceed for prolonged periods of time (at least 72 h), at which OD₆₀₀ values of up to 7 to 10 were obtained (data not shown). Hydrogen consumption and methane production rates, as well as dissolved hydrogen partial pressures, however, remained constant throughout the whole period of linear growth.

Growth rates, growth yields, and methane-forming activities in the fed-batch fermentor system. As noted above, three consecutive growth phases could be discerned, notably the lag, exponential, and linear phases. The exponential phase is usually determined from the straight section of the graphs in which the (natural) logarithm of biomass (or OD) is plotted against