The activity of polyclonal IgY derived from *Aggregatibacter actinomycetemcomitans* and *Porphyromonas gingivalis* in inhibiting colonization of *Fusobacterium nucleatum* and *Streptococcus sanguinis*

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ABSTRACT

**Background:** *Fusobacterium nucleatum* (F. nucleatum) and *Streptococcus sanguinis* (S. sanguinis) play a role in dental plaque formation which leads to periodontitis. Immunoglobulin Y (IgY) is present in both serum and egg yolk and can bind to the surface components of bacteria. *F. nucleatum* and *S. sanguinis* feature the same type of IV pili as *Aggregatibacter actinomycetemcomitans* (A. actinomycetemcomitans). Saliva binding protein (SsaB) in *S. sanguinis* is a FimA homolog. FimA constitutes a surface element of *Porphyromonas gingivalis* (P. gingivalis). *F. nucleatum* and *P. gingivalis* possess the same outer membrane protein (OMP) molecular mass. **Purpose:** The study aimed to determine the activity of *A. actinomycetemcomitans* and *P. gingivalis* polyclonal IgY present in serum and egg yolk that can inhibit colonization of *F. nucleatum* and *S. sanguinis*. **Methods:** IgY samples were diluted with phosphate buffer saline (PBS). Several holes were made in the nutrient medium with 10 μl antigen (*F. nucleatum*/S. sanguinis) being inserted into the center hole. 10 μl PBS, 1:1, 1:2, 1:4, 1:8, 1:16 A. actinomycetemcomitans or P. gingivalis polyclonal IgY were subsequently introduced into the surrounding holes. The results of incubation at 37°C were observed after 24-48 hours. Kruskal Wallis and Mann-Whitney tests were administered to analyse the data. **Results:** A. actinomycetemcomitans and P. gingivalis polyclonal IgY groups in serum showed a precipitation line at dilution ratios of 1:1 and 1:2, whereas in egg yolk this occurred only at a 1:1 dilution ratio with *F. nucleatum* and *S. sanguinis* bacteria in this study. No significant differences were evident between each dilution (p>0.05) and none existed between serum and egg yolk (p>0.05). **Conclusion:** IgY polyclonal of *A. actinomycetemcomitans* and *P. gingivalis* in both serum and egg yolk initiate activities that can inhibit colonization of *F. nucleatum* and *S. sanguinis*. **Keywords:** *Aggregatibacter actinomycetemcomitans*; *Fusobacterium nucleatum*; IgY; *Porphyromonas gingivalis*; *Streptococcus sanguinis*

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INTRODUCTION

Gingivitis generally occurs between 10 and 21 days after dental plaque formation under poor and untreated oral hygiene conditions and can develop into periodontitis.\(^1\) The latter condition results from ecological imbalances between microbial communities in dental bioloids that support the growth of *Streptococcus* pathogenic bacteria.\(^2\)*Streptococcus sanguinis* (S. sanguinis) constitutes a pioneer bacterium on the tooth surface which plays an important role in plaque maturation due to its ability to aggregate with other bacteria resulting in periodontal disease.\(^3\) The initiation and development of periodontitis is caused by *Aggregatibacter actinomycetemcomitans* (A. actinomycetemcomitans), *Porphyromonas gingivalis* (P. gingivalis), *Tannerella forsythia* (T. forsythia), *Treponema denticola* (T. denticola), *Prevotella intermedia* (P. intermedia) and *Fusobacterium nucleatum* (F. nucleatum) bacteria.\(^4\) Inhibition of plaque matrix formation and initiation of bacterial aggregation can prevent initial colonization with the result that final
colonization does not occur.\textsuperscript{5} \textit{F. nucleatum} and \textit{S. sanguinis} bacteria promote the formation of dental plaque that can cause periodontitis.

Over the past two decades, dentists have applied antibiotic therapy to periodontal disease treatment.\textsuperscript{6} In addition, mouthwash, the main component of which is chlorhexidine, can prevent plaque formation.\textsuperscript{7} To reduce antibiotic resistance and the side effects of chlorhexidine gluconate mouthwash such as taste disorders, oral irritation and local allergy symptoms, an unprecedented therapeutic approach is required. One potential strategy is to explore passive oral immunotherapy using Immunoglobulin Y (IgY) as a control method in inhibiting dental plaque.\textsuperscript{7,8} IgY is one class of antibody contained in the blood serum and egg yolk of amphibian, reptilian and poultry groups.\textsuperscript{9} IgY constitutes a polyclonal antibody that has been shown to be effective in the prevention and treatment of several diseases.\textsuperscript{10} Moreover, its low cost and simple production process renders this antibody suitable for research and diagnosis.\textsuperscript{11}

IgY can inhibit the attachment of bacteria to host cells\textsuperscript{12} since IgY antibacterium binds to certain components on the target bacteria surface such as outer membrane protein (OMP), lipopolysaccharide (LPS), flagella and fimbriae.\textsuperscript{13} It has been reported that \textit{A. actinomyctecomitans} contains type IV pili.\textsuperscript{14} Type IV pili are also expressed by other Gram-positive pathogens such as \textit{Clostridium perfringens} (\textit{C. perfringens}) and \textit{S. sanguinis}.\textsuperscript{15} Phenotyping screening also confirms type IV pili to be present on the cell surface of \textit{F. nucleatum}.\textsuperscript{16} \textit{P. gingivalis} pili contains FimA.\textsuperscript{17} \textit{S. sanguinis} bacteria carry SsaB, a FimA homolog, on their surface. Bacterial adhesion molecules play an important role in the adhesion between bacteria and host cell.\textsuperscript{18} \textit{P. gingivalis} and \textit{F. nucleatum} have an outer membrane protein with a molecular mass of 40-kDa.\textsuperscript{19} Against this background, the research aim was to determine whether IgY anti \textit{A. actinomyctecomitans} and \textit{P. gingivalis} can be employed to inhibit colonization of \textit{F. nucleatum} and \textit{S. sanguinis} bacteria.

**MATERIALS AND METHODS**

The type of research employed an experimental laboratory methodology. The samples analyzed comprised polyclonal IgY anti-\textit{A. actinomyctecomitans} and polyclonal IgY anti-\textit{P. gingivalis} in serum and egg yolk. More than three replications were produced, their number being determined by the Federer formula. The polyclonal IgY contained in the serum and egg yolk produced by hens previously injected four times (booster) with \textit{A. actinomyctecomitans} serotype b strain Y4 ATCC 4371 and \textit{P. gingivalis} ATCC 3327 was subsequently analyzed using Elisa.\textsuperscript{11} The research method employed was granted ethical clearance (certificate number: 294/HRECC.FODM/XII/2018) by the Faculty of Dental Medicine, Universitas Airlangga.

Serum was diluted with phosphate buffer saline (PBS) at a ratio of 1:16. Each vial/bottle contained 20 μl of assay buffer. The contents of the first vial were mixed with 20 μl serum samples at a dilution level of 1:1. 20 μl of the 1:1 sample dilution were subsequently transferred to a second vial where they were further diluted at a ratio of 1:2. 20 μl of the sample were transferred to a third vial where the dilution rate was one of 1:4. 20 μl of the sample was transferred to the fifth vial and diluted at a rate of 1:16. This procedure was repeated for the IgY samples in egg yolk.\textsuperscript{20}

The nutrient medium solution was cooled to 50-60°C, placed in 15 ml petri dishes on a horizontal surface and

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**Figure 1.** The precipitation line of \textit{A. actinomyctecomitans} polyclonal IgY groups in serum and egg yolk in \textit{F. nucleatum} and \textit{S. sanguinis}. (S/S: \textit{S. sanguinis} IgY in Serum; S/T: \textit{S. sanguinis} IgY in egg yolk; F/S: \textit{F. nucleatum} IgY in serum; F/T: \textit{F. nucleatum} IgY in egg yolk).

**Figure 2.** Result diagrams of the \textit{A. actinomyctecomitans} polyclonal IgY group in bacteria: a) \textit{F. nucleatum}; b) \textit{S. sanguinis}; a) Serum preparation; b) Egg yolk preparation.
RESULTS

This study confirmed inhibition of the colonization of F. nucleatum and S. sanguinis bacteria in the A. actinomycetemcomitans polyclonal IgY group present in serum and egg yolk (Figure 1). Based on these results, the IgY anti-A. actinomycetemcomitans group in the serum showed a precipitation line against F. nucleatum and S. sanguinis at 1:1 and 1:2 dilutions of the treatment groups. In contrast, the IgY anti-A. actinomycetemcomitans group in the egg yolk showed the presence of precipitation lines.

Table 1. Data analysis of A. actinomycetemcomitans polyclonal IgY group and F. nucleatum

<table>
<thead>
<tr>
<th>Antigen</th>
<th>AA1 (1:1)</th>
<th>AA2 (1:2)</th>
<th>AA3 (1:4)</th>
<th>AA4 (1:8)</th>
<th>AA5 (1:16)</th>
<th>AA6 (PBS)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>F/S</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.051</td>
</tr>
<tr>
<td>F/T</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.051</td>
</tr>
</tbody>
</table>

Table 2. Data analysis of A. actinomycetemcomitans polyclonal IgY group and S. sanguinis

<table>
<thead>
<tr>
<th>Antigen</th>
<th>AA1 (1:1)</th>
<th>AA2 (1:2)</th>
<th>AA3 (1:4)</th>
<th>AA4 (1:8)</th>
<th>AA5 (1:16)</th>
<th>AA6 (PBS)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>S/S</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.051</td>
</tr>
<tr>
<td>S/T</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.051</td>
</tr>
</tbody>
</table>

Table 3. Comparison of the results of A. actinomycetemcomitans polyclonal IgY group in the serum and egg yolk and F. nucleatum and S. sanguinis

<table>
<thead>
<tr>
<th>Antigen</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>F/S</td>
<td>0.514</td>
</tr>
<tr>
<td>F/T</td>
<td>0.514</td>
</tr>
</tbody>
</table>

Note: *: significance (p value <0.05)

Table 4. Data analysis of P. gingivalis polyclonal IgY and F. nucleatum

<table>
<thead>
<tr>
<th>Antigen</th>
<th>PG1 (1:1)</th>
<th>PG2 (1:2)</th>
<th>PG3 (1:4)</th>
<th>PG4 (1:8)</th>
<th>PG5 (1:16)</th>
<th>PG6 (PBS)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>F/S</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.051</td>
</tr>
<tr>
<td>F/T</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.051</td>
</tr>
</tbody>
</table>

Table 5. Data analysis of P. gingivalis polyclonal IgY and S. sanguinis

<table>
<thead>
<tr>
<th>Antigen</th>
<th>PG1 (1:1)</th>
<th>PG2 (1:2)</th>
<th>PG3 (1:4)</th>
<th>PG4 (1:8)</th>
<th>PG5 (1:16)</th>
<th>PG6 (PBS)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>S/S</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
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<td>-</td>
<td>0.051</td>
</tr>
<tr>
<td>S/T</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.051</td>
</tr>
</tbody>
</table>

Note: +: there is a precipitation line; -: there is no precipitation line; *: significance (p value <0.05)
against *F. nucleatum* and *S. sanguinis* during 1:1 dilution treatment. Data analysis was performed with a Kruskal Wallis test, the results of which are contained in Tables 1 and 2, and a Mann-Whitney test whose results are shown in Table 3.

Based on the contents of Tables 1 and 2, it is evident that none of the F/S, F/T, S/S and S/T groups showed significant value because the p value equaled 0.051 which was greater than 0.05 (p>0.05). This figure indicated that the concentration had no effect on the results. The data in Table 3 indicates that the value of F/S with F/T was 0.514, while that of S/S with S/T was 0.514. These results, arrived at through statistical calculation, indicated no difference between the polyclonal IgY group of *A. actinomycetemcomitans* in serum and egg yolk and *F. nucleatum* and *S. sanguinis*. They were considered to be insignificant with a p value >0.05. This study confirmed colonization inhibition of *F. nucleatum* and *S. sanguinis* bacteria of the IgY anti-*P. gingivalis* group in serum and egg yolk which can be characterized by the precipitation line shown in Figure 3.

These results of the IgY anti-*P. gingivalis* group in serum showed a precipitation line for the *F. nucleatum* and *S. sanguinis* bacteria occurring at 1:1 and 1:2 dilutions in the treatment groups. By contrast, in the *P. gingivalis* polyclonal IgY group, egg yolk showed the presence of precipitation lines in the *F. nucleatum* and *S. sanguinis* bacteria in the 1:1 dilution treatment group. Data analysis was performed by means of a Kruskal Wallis test, the results of which are shown in Table 4 and 5, and a Mann-Whitney test whose results appear in Table 6.

Based on contents of Tables 4 and 5, it is known that none of the F/S, F/T, S/S and S/T group showed significant values because the p value equaled 0.051, indicating that it was higher than 0.05 (p>0.05). This indicated that concentration had no effect on the results. The contents of Table 6 show that the value of F/S with F/T was 0.514, while that of S/S with S/T was 0.514. These statistical calculation-based results showed no difference between the polyclonal IgY group of *P. gingivalis* in serum and egg yolk in the *F. nucleatum* and *S. sanguinis* bacteria due to insignificant results since the p value >0.05.

**DISCUSSION**

This study used IgY anti-*A. actinomycetemcomitans* and IgY anti-*P. gingivalis* in serum and egg yolk to be tested against two other bacteria, i.e. *F. nucleatum* and *S. sanguinis*, using a double immunodiffusion method. *A. actinomycetemcomitans* polyclonal IgY and *P. gingivalis* polyclonal IgY were obtained from chickens previously immunized with specific antigens i.e. *A. actinomycetemcomitans* or *P. gingivalis* prior to serum being taken. Testing of the two polyclonal IgY was conducted using a double immunodiffusion method.

The results of the data from the IgY anti-*A. actinomycetemcomitans* group for serum in the *F. nucleatum* and *S. sanguinis* bacteria, found a formation precipitation line at 1:1 and 1:2 dilutions. In contrast, for the IgY anti-*A. actinomycetemcomitans* group in egg yolk formation of a precipitation line occurred at 1:1 dilution in the *F. nucleatum* and *S. sanguinis* bacteria.

Similar results were found in the IgY anti-*P. gingivalis* group. The results of the IgY anti-*P. gingivalis* group in serum for *F. nucleatum* and *S. sanguinis* bacteria found the precipitation line at 1:1 and 1:2 dilutions. Contrastingly, in the IgY anti-*P. gingivalis* group in egg yolk, a precipitation line formed at 1:1 dilution in *F. nucleatum* and *S. sanguinis* bacteria. These results show that precipitation lines are formed at low dilutions and that the concentration of antibodies in dilution is higher than that of other dilution groups, meaning that the group with low dilution levels is of an appropriate concentration to be able to interact with

**Figure 3.** The precipitation line of IgY anti-*P. gingivalis* group in the serum and egg yolk in *F. nucleatum* and *S. sanguinis*. (S/S: *S. sanguinis*/IgY in serum; S/T: *S. sanguinis*/IgY in egg yolk; F/S: *F. nucleatum*/IgY in serum; F/T: *F. nucleatum*/IgY in egg yolk).

**Figure 4.** Result diagrams of IgY anti-*P. gingivalis* group in *F. nucleatum* and *S. sanguinis*: a) serum preparation; b) Egg yolks preparation.
the antigen. Excessively low antibody concentration will produce negative results similar to those of previous research conducted by Sharon et al. in which the precipitation line occurred at 1:2 dilution.

The precipitation lines formed between antigens and antibodies, both in the IgY anti-A. actinomycetemcomitans group in serum and egg yolk for F. nucleatum and S. sanguinis bacteria, and IgY anti-P. gingivalis group in serum and egg yolk for F. nucleatum and S. sanguinis bacteria, indicated some form of activity between the IgY anti-A. actinomycetemcomitans with F. nucleatum and S. sanguinis, as well as between the IgY anti-P. gingivalis with F. nucleatum and S. sanguinis. The activity took the form of binding between antibodies and antigens, possibly because IgY is a polyclonal antibody that can bind to various epitope antigens. IgY anti-A. actinomycetemcomitans can bind to pili from bacteria, such as F. nucleatum and S. sanguinis, because all have type IV pili. Polyclonal IgY P. gingivalis can also bind to the homologous element found on the surface of S. sanguinis, namely SsaB, and can bind to OMP F. nucleatum because it possesses the same molecular mass. This binding can inhibit the colonization of F. nucleatum and S. sanguinis bacteria due to the disruption of the function of the surface components of these bacteria which can be useful for their adhesion.

Previous research conducted by Lee et al. showed that Salmonella specific IgY binds to Salmonella surface molecules with the result that it can inhibit homologous Salmonella growth. IgY can affect colonization of Salmonella enteritidis and Salmonella typhimurium by binding to OMP. OMP Salmonella is useful for adhesion and mucosal invasion. The binding causes disruption of OMP biological function, with the result that invasive Salmonella is reduced due to the loss of ability to colonize the digestive tract.

The results of the statistical analysis indicated no difference between the inhibitory colonization in the polyclonal IgY A. actinomycetemcomitans dilution group and the polyclonal IgY P. gingivalis group. This is consistent with the theory that this test is less sensitive because the formation of precipitation lines depends on the equivalent concentration of antigen antibodies and specific antibodies. It can be concluded that the activities of A. actinomycetemcomitans and P. gingivalis polyclonal IgY in serum and egg yolk can inhibit colonization of F. nucleatum and S. sanguinis.

REFERENCES